Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

84 B
no. 278

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 278

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 5, 1915

MISCELLANEOUS INSECTICIDE INVESTIGATIONS

By

E. W. SCOTT and E. H. SIEGLER, Entomological Assistants,
Deciduous-Fruit Insect Investigations

CONTENTS

	Page		Page
Introduction	1	Field Experiments	27
Experiments, 1912	1	Summarized Review	38
Experiments, 1913	11	Conclusions	42
Experiments, 1914	19	Key to Tables	43

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 278

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPER. October 5, 1915

MISCELLANEOUS INSECTICIDE INVESTIGATIONS.[1]

By E. W. Scott and E. H. Siegler, *Entomological Assistants, Deciduous-Fruit Insect Investigations.*

CONTENTS.

	Page.		Page.
Introduction	1	Field experiments	27
Experiments, 1912	1	Summarized review	38
Experiments, 1913	11	Conclusions	42
Experiments, 1914	19	Key to tables	43

INTRODUCTION.

Numerous experiments with miscellaneous insecticides and spray combinations, including tests of a new and promising arsenical, namely, arsenate of calcium, were conducted in connection with other work at the field station for deciduous-fruit insect investigations, at Benton Harbor, Mich., during the seasons of 1912, 1913, and 1914. Various homemade and proprietary insecticides, alone and in combination with other sprays, were tested in the laboratory and in the field. This work was done under the instructions of Dr. A. L. Quaintance, in charge of Deciduous-Fruit Insect Investigations, and much valuable assistance in carrying out the work was rendered by Messrs. J. H. Paine, H. G. Ingerson, and D. M. Hamilton.

EXPERIMENTS, 1912.

A series of poison-feeding experiments were made to determine the comparative killing effect of various arsenicals and also doubtful stomach poisons on different species of chewing insects. At the beginning of the tests 32 different materials were used, but since the

[1] See key to the table of insecticides on page 43.

Note.—This bulletin describes experiments with various chemicals, singly and combined, for the destruction of insect pests. It will be of interest to horticulturists in general and apple growers in particular.

98119°—Bull. 278—15——1

first few experiments showed that many of these were of little value as stomach poisons, their use was discontinued.

A few homemade preparations were tested in the course of these experiments. Those used in 1912 were arsenate of iron, arsenate of zinc, and arsenite of lime. The methods of preparation of these materials were as follows:

Arsenate of iron was prepared by dissolving 4 pounds of sodium-arsenate crystals and 4 pounds of iron sulphate each in 2 gallons of hot water. The iron-sulphate solution was then poured slowly into the sodium-arsenate solution, the solution being stirred vigorously at the same time. Arsenate of iron was used at a rate equal to 0.8 pound of sodium arsenate to 50 gallons of water for the ordinary strength.

The arsenate of zinc (homemade) was prepared in the same way as arsenate of iron, sodium arsenate and zinc sulphate being used, and the strength being based upon the sodium-arsenate content, the same as for arsenate of iron.

Arsenite of lime was prepared by boiling 2 pounds of white arsenic and 2 pounds of sal soda in 1½ gallons of water until thoroughly dissolved, and this was used to slake 4 pounds of stone lime. After slaking, enough water was added to bring the total to 2 gallons. This was used at the rate of 2 pints to 50 gallons of water, which is equivalent to one-fourth pound of white arsenic to 50 gallons of water.

LABORATORY TESTS.

During the season of 1912 the fall webworm (*Hyphantria cunea* Drury) was used for all the experiments, since this insect could be readily obtained in large numbers, and proved to be an ideal species for handling in the laboratory. Very young larvæ, usually 3 or 4 days old, were used in all the tests. The larvæ were fed with foliage of the wild black cherry (*Prunus serotina*), which was found to be a favorite food plant of the fall webworm in Michigan. Twigs having from 20 to 30 leaves each were sprayed by means of a large atomizer of the type in which quart jars are used as a container for the liquid, and the stems of the twigs were placed in small glass jars containing water.

After the spray had thoroughly dried, allowing from 6 to 12 hours, 20 insects were placed on the leaves of each twig. A large paper bag was then placed over the twig and held to the glass by means of a rubber band to prevent the escape of the larvæ. At each examination the bag was removed and the dead larvæ taken out and counted. When all the insects were dead or had pupated, as the case might be, the amount of foliage consumed was measured in square inches. A sheet of celluloid, cross-sectioned to 0.01 of a square inch, was utilized for this purpose. These measurements were easily taken where effective poisons were used, as the young larvæ died before very

much foliage had been consumed. In other cases, where the entire leaf except the midrib and larger veins was consumed, the measurement was obtained by measuring an average-sized leaf and substituting it for the leaf which had been destroyed. Careful attention was given to the condition of the foliage throughout the experiments so as to supply the larvæ with palatable food at all times.

Experiment I.

Comparison of the killing effect of doubtful stomach poisons with various arsenicals on larvæ of the fall webworm.

In this experiment the arsenite of zinc compounds and other proprietary insecticides were used at the strengths recommended by the manufacturers. The homemade arsenical compounds, where sodium arsenate was employed, were used at a rate to equal 0.8 pound sodium-arsenate content to 50 gallons of water, except in the case of arsenate of iron, which was used double strength. Arsenite of lime, homemade, was used at the rate of 2 pints to 50 gallons of water. All other compounds containing arsenic were used at a strength equivalent to 2 pounds of arsenate of lead paste to 50 gallons of water. These calculations were based upon a 15 per cent arsenic-oxid (As_2O_5) content in arsenate of lead paste. Compounds containing no arsenic were used at the rate of 6 pounds to 50 gallons of water. The larvæ used in this test were about 4 days old. The results are given in Table I.

TABLE I—*Tests of the killing effect of various arsenicals and doubtful stomach poisons on the fall webworm.*

[Experiment started July 13, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying on each date.																						Number of larvæ pupated.	Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.														August.					September.		October.					
	15	16	17	18	19	20	21	22	23	24	25	26	27	29	2	4	8	14	25	2	13	3	18				
Arsenate of lead,[1] di., 1–55	3	2	7	1	4	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	0.23
Arsenate of lead, tri., 1–42	2	4	1	3	4	2	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	9	.28
Arsenate of lead, di. and tri., 1–50	1	1	3	1	2	6	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	8	1.40
Arsenate of lead, triplumbic, com. (1), 2–50	1	1	1	2	3	1	0	2	2	3	1	1	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 18	13	.70
Arsenate of lead, com. (2), 2–50	5	7	5	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.37
Arsenate of lead, com. (3), 2–50	3	6	6	3	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.39
Arsenate of calcium, c. p. (powder), 1–52	4	2	3	4	1	2	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 18	9	.02
Arsenate of iron, c. p. (powder), 2–50	4	7	2	0	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 16	8	.17
Arsenate of iron, h. m., $1\frac{6}{10}$–50	9	3	3	0	2	0	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	9	.40
Arsenate of zinc, c. p. (powder), 1–46	1	4	4	3	0	2	2	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	10	.46
Arsenate of zinc, h. m., $\frac{8}{10}$–50	0	6	9	4	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	6	.12
Arsenic sulphid, 1–54	0	0	2	0	0	3	0	0	0	0	0	1	1	9	3	....	....	....	....	....	....	....	....	.....	[2] 19	19	2.80
Arsenic tersulphid, ½–50	1	5	8	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 18	5	.16
Arsenic trioxid, ½–56	1	3	7	2	3	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.25
Arsenite of lime, 2 pts.–50	2	4	3	1	1	3	4	1	0	1	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	11	.33
Arsenite of zinc[1] (1), ½–43	6	12	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	5	.12
Arsenite of zinc (2), 1½–50	6	0	3	2	2	2	0	2	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	12	.60
Arsenite of zinc (3), ¾–50	2	3	0	1	1	0	0	3	6	2	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 18	11	.93
Arsenite of zinc (4), ¾–50	8	8	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	4	.07
Barium chlorid, 6–50	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	4	[2] 10	97	67.75
Barium sulphate, 6–50	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	3	....	4	[2] 8	82	99.86
Calcium chlorid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	3	0	1	7	[2] 7	97	62.00
Copper oxid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	1	0	2	8	[2] 9	97	176.00
Lead acetate, 6–50	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	2	0	1	0	2	4	[2] 9	97	122.00
Lead carbonate, 6–50	0	1	0	0	1	2	2	0	0	0	0	0	0	0	2	0	0	1	1	1	0	0	....	6	[2] 11	82	80.00
Lead chromate, 4–50	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	1	7	3	....	....	....	....	.....	[2] 16	43	3.72
Lead oxid, 6–50	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	....	....	5	[2] 6	62	81.96
Lead peroxid, 6–50	0	2	0	0	0	0	0	1	0	1	.1	1	1	1	0	0	0	0	0	1	1	1	....	.....	[2] 10	82	18.90
Mercury bichlorid, ¾–50	0	2	1	2	2	1	3	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2] 17	9	.27
Zinc chlorid, 3–50	1	0	0	0	1	1	0	0	0	0	0	0	1	2	1	4	3	....	....	....	....	....	....	.....	[2] 14	26	3.73
Zinc oxid, 6–50	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	8	1	2	....	....	.....	[2] 16	62	9.48
Zinc sulphate, 6–50	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	4	5	0	0	1	.....	[2] 14	97	12.37
Check (unsprayed) 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	....	9	[2] 4	82	155.55
Check (unsprayed) 2	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	....	12	[2] 7	82	131.38
Check (unsprayed) 3	0	0	0	0	0	0	0	0	0	0	.0	0	0	0	0	0	0	0	1	1	0	0	....	9	[2] 3	82	192.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powder; com. (1), (2), (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial; c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

As will be noted, while the triplumbic arsenate of lead was very effective against the larvæ, it was somewhat slower in its killing effect than the diplumbic and the mixture of diplumbic and triplumbic arsenate of lead. This held true in the other experiments that follow. Of the three commercial arsenates of lead, commercial (1), which consisted of the triplumbic form, required a greater length of time to kill the larvæ than was required by the other two commercial brands, which consisted mainly of the diplumbic form.

Arsenate of iron, both chemically pure and homemade, was used at double strength, owing to indications of slow killing effect in previous tests. At this strength it was somewhat slower than many of the other arsenicals. Like results will be noted in later experiments with this material.

The arsenates of zinc were effective and seemed to be safe to use on the foliage.

Arsenic sulphid, arsenic tersulphid, arsenic trioxid, arsenite of lime, and the arsenites of zinc were effective, but burned the foliage more or less seriously.

Mercury bichlorid and zinc chlorid, while effective, were very injurious to the foliage.

All the other compounds were ineffective.

Experiment II.

Comparison of the killing effect of various arsenicals and doubtful stomach poisons combined with lime-sulphur solution on larvæ of the fall webworm.

In Table II are given the results of using lime-sulphur at the rate of 1½ gallons to 50 gallons of spray in combination with all the materials used. Little difference was noted from the use of these combinations of lime-sulphur with the arsenicals. However, in case of the materials which had no effect on the larvæ when used alone a marked difference was evident from the addition of lime-sulphur. In all cases the larvæ were killed, the length of time of killing varying considerably with the material used. The difference no doubt was largely due to the difference in chemical reaction between the material and the lime-sulphur. Lime-sulphur alone killed the 20 larvæ in 15 days with only 0.73 square inches of foliage consumed. In Table II are shown the results.

TABLE II.—*Tests of the killing effect of various arsenicals and doubtful stomach poisons combined with lime-sulphur on the fall webworm.*

[Experiment started July 20, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.																									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.									August.														September.				
	22	23	24	25	26	27	28	29	31	2	4	6	8	10	12	14	16	19	21	24	26	28	2	19	30			
Lime-sulphur, 1½–50, combined with the following:																												
Arsenate of lead,[1] di., 1–55	0	1	1	0	2	4	1	4	5	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	13	0.16
Arsenate of lead,[1] tri., 1–42	0	0	0	1	0	3	0	3	6	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 16	15	2.25
Arsenate of lead,[1] di. and tri., 1–50	2	1	1	4	4	7	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.15
Arsenate of lead,[1] triplumbic, com. (1), 2–50	1	2	0	1	0	5	0	5	4	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 19	13	.44
Arsenate of lead,[1] com. (2), 2–50	4	3	3	4	2	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.02
Arsenate of lead,[1] com. (3), 2–50	0	0	1	7	10	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.12
Arsenate of calcium, c. p.[1] (powder), 1–50	0	1	1	4	3	5	3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.13
Arsenate of iron, c. p.[1] (powder), 1–50	0	0	2	3	3	8	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 18	9	.39
Arsenate of iron, h. m.,[1] $\frac{8}{10}$–50	0	1	5	6	2	1	0	1	1	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	15	1.22
Arsenate of zinc, c. p.[1] (powder), 1–46	0	0	1	7	2	6	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.15
Arsenate of zinc, h. m.,[1] $\frac{8}{10}$–50	2	1	4	1	6	4	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.33
Arsenic sulphid, 1–54	1	1	0	5	9	0	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.10
Arsenic tersulphid, ½–50	0	0	3	5	4	3	0	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 17	9	.007
Arsenic trioxid, ½–56	0	0	2	14	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.06
Arsenite of lime,[1] h. m., 2 pts–50	1	1	2	2	1	1	4	5	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.22
Arsenite of zinc[1] (1), ½–43	0	0	3	5	5	6	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.12
Arsenite of zinc[1] (2), 1½–50	0	1	8	3	5	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 19	7	.06
Arsenite of zinc[1] (3), ¾–50	0	0	1	1	2	6	9	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.25
Arsenite of zinc[1] (4), ¾–50	0	0	2	3	3	3	2	3	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	13	.26
Barium chlorid, 6–50	0	0	0	1	0	0	0	0	0	5	3	2	5	3	1	....	....	....	....	....	....	....	....	....	....	20	23	2.52
Barium sulphate, 6–50	0	0	0	0	0	2	2	1	5	3	0	1	3	1	0	2	....	....	....	....	....	....	....	....	....	20	25	2.60
Calcium chlorid, 6–50	0	0	0	0	1	3	1	6	1	3	1	3	1	....	....	....	....	....	....	....	....	....	....	....	....	20	19	2.48
Copper oxid, 6–50	0	0	0	1	4	4	3	6	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.68
Lead acetate, 6–50	0	0	1	2	4	3	1	0	1	1	0	0	1	1	2	....	....	....	....	....	....	....	....	....	....	[2] 17	23	1.33
Lead carbonate, 6–50	0	1	0	2	2	2	4	2	2	1	0	0	0	0	1	0	0	0	0	2	....	....	....	....	....	[2] 19	35	3.12
Lead chromate, 6–50	0	0	0	0	0	7	3	7	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.50
Lead oxid, 6–50	0	0	0	0	1	1	0	3	3	2	1	0	1	0	2	2	2	0	0	0	1	0	1	....	....	20	44	9.52
Lead peroxid, 6–50	0	0	0	0	0	0	1	2	1	0	1	2	2	4	1	3	3	....	....	....	....	....	....	....	....	20	27	14.70
Mercury bichlorid, ¾–50	0	0	0	0	1	1	3	3	3	3	0	0	2	0	0	0	0	3	0	0	1	....	....	....	....	20	37	5.41
Zinc chlorid, 3–50	0	0	0	0	10	8	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.62
Zinc oxid, 6–50	0	0	0	0	1	3	3	2	2	0	1	0	2	2	0	3	0	0	0	1	....	....	....	....	....	20	35	7.00
Zinc sulphate, 6–50	0	0	0	0	0	3	0	0	2	0	0	0	1	2	1	1	1	1	3	1	0	0	2	....	....	[2] 18	44	8.63
Lime-sulphur, 1½–50	0	0	0	0	4	3	3	4	4	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	15	.73
Check (unsprayed) (1)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	4	72	243.20
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	....	....	2	61	162.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powders; com. (1), (2), and (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial. c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

Experiment III.

COMPARISON OF THE KILLING EFFECT OF VARIOUS ARSENICALS ON LARVÆ OF THE FALL WEBWORM.

In this experiment the same arsenicals were used as in Experiment I, all the other materials being omitted. However, since half-grown larvæ were used the strength of the materials was doubled. The results are shown in Table III.

TABLE III.—*Tests of the killing effect of various arsenicals on the fall webworm. Larvæ half grown.*

[Experiment started July 24, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.					August.						
	26	27	28	29	31	2	4	7	12			
Arsenate of lead, di., 2–55	0	0	1	4	15	....	....	....	....	20	7	1.22
Arsenate of lead, tri., 2–42	0	0	0	1	1	7	8	3	....	20	14	.60
Arsenate of lead, di. and tri., 2–50	0	2	2	3	9	4	....	....	....	20	9	.43
Arsenate of lead, triplumbic, com. (1), 4–50	0	1	2	1	12	2	1	1	....	20	14	.84
Arsenate of lead, com. (2), 4–50	1	0	3	6	10	....	....	....	....	20	7	.94
Arsenate of lead, com. (3), 4–50	0	0	5	10	5	....	....	....	....	20	7	.37
Arsenate of calcium, c. p. (powder), 2–50	0	0	1	0	10	4	5	....	....	20	11	1.15
Arsenate of iron, c. p. (powder), 4–50	0	0	0	1	1	3	1	4	2	12	19	[2]
Arsenate of iron, h. m., $3\frac{1}{2}$–50	0	0	1	1	1	1	1	2	2	9	19	[2]
Arsenate of zinc, c. p. (powder), 2–46	4	0	0	5	11	....	....	....	....	20	7	2.03
Arsenate of zinc, h. m., $1\frac{6}{7}$–50	0	0	1	7	7	2	1	2	....	20	14	.87
Arsenic sulphid, 2–54	3	0	2	7	8	....	....	....	....	20	7	.95
Arsenic tersulphid, 1–50	4	1	3	5	3	4	....	....	....	20	9	.19
Arsenic trioxid, 1–56	5	6	4	0	3	1	....	....	....	[1] 19	9	.06
Arsenite of lime, 4 pts.–50	1	0	3	10	6	....	....	....	....	20	7	.56
Arsenite of zinc, c. p. (1), 2–43	3	0	2	9	4	....	....	....	....	[1] 18	7	.15
Arsenite of zinc, com. (2), 3–50	0	0	3	1	12	4	....	....	....	20	9	1.08
Arsenite of zinc, com. (3), $1\frac{1}{2}$–50	0	1	2	5	5	7	....	....	....	20	9	.94
Arsenite of zinc, com. (4), $1\frac{1}{2}$–50	0	0	1	3	9	6	....	....	....	[1] 19	9	.41
Check (unsprayed) (1)	0	0	0	0	0	0	0	0	0	0	19	[2]
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	19	[2]

[1] Remainder escaped. [2] Not measured.

The results of these tests agree very well with the results obtained from Experiment I. The experiment was discontinued August 12, when all the larvæ were dead except in the case of arsenate of iron, chemically pure, where 8 larvæ still remained living, and arsenate of iron, homemade, where 11 remained living. All the larvæ on the unsprayed lots were alive at the time the experiment was closed.

Experiment IV.

FIELD TESTS OF VARIOUS ARSENICALS AGAINST THE CODLING MOTH IN MICHIGAN, 1912.

Several arsenicals were tested in comparison with arsenate of lead against the codling moth in Mr. J. T. Beckwith's apple orchard in the vicinity of Benton Harbor. The trees were of the Ben Davis variety and about 35 years of age. The plats consisted of from 4 to 12 trees, and the fruit was counted from 3 trees of each plat. The extent of foliage injury from the various sprays was also noted. The homemade

preparations were prepared and diluted as given on page 2. The results against the codling moth are shown in Table IV.

TABLE IV.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1912.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	64	4,430	4,494	98.58
		2	14	1,542	1,556	99.10
		3	9	879	888	98.98
	Plat total		**87**	**6,851**	**6,938**	**98.74**
II	Arsenate of lead (paste) commercial No. 1 (triplumbic), 2 pounds to 50 gallons lime-sulphur solution	1	33	874	907	96.36
		2	84	1,727	1,811	95.36
		3	44	1,115	1,159	96.20
	Plat total		**161**	**3,716**	**3,877**	**95.85**
III	Arsenite of zinc (powder), ¾ pound to 50 gallons lime-sulphur solution	1	4	734	738	99.46
		2	20	1,110	1,130	98.23
		3	15	744	759	98.02
	Plat total		**39**	**2,588**	**2,627**	**98.52**
IV	Arsenite of zinc (paste), 1½ pounds to 50 gallons lime-sulphur solution	1	19	1,387	1,406	98.65
		2	27	2,638	2,665	98.99
		3	7	486	493	98.58
	Plat total		**53**	**4,511**	**4,564**	**98.83**
V	Arsenite of lime, homemade, 2 pints to 50 gallons lime-sulphur solution	1	32	680	712	95.50
		2	75	1,282	1,357	94.47
		3	52	1,201	1,253	95.85
	Plat total		**159**	**3,163**	**3,322**	**95.21**
VI	Arsenate of zinc, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	80	1,030	1,110	92.79
		2	261	1,597	1,858	85.95
		3	108	1,257	1,365	92.09
	Plat total		**449**	**3,884**	**4,333**	**89.63**
VII	Arsenate of iron, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	174	942	1,116	84.41
		2	413	1,176	1,589	74.01
		3	254	1,228	1,482	82.86
	Plat total		**841**	**3,346**	**4,187**	**79.91**
VIII	Arsenate of iron, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	228	800	1,028	77.82
		2	205	970	1,175	82.55
		3	537	1,466	2,003	73.19
	Plat total		**970**	**3,236**	**4,206**	**76.93**
IX	Arsenate of calcium, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	205	1,672	1,877	89.03
		2	95	529	624	84.77
		3	160	847	1,007	84.11
	Plat total		**460**	**3,048**	**3,508**	**86.88**
X	Check (unsprayed)	1	257	231	488	47.33
		2	487	274	761	36.01
		3	744	445	1,189	37.43
	Plat total		**1,488**	**950**	**2,438**	**38.96**

Arsenate of lead held the codling moth to 98.74 per cent of fruit free from worms, with no foliage injury resulting. Commercial arsenate of lead No. 1 (triplumbic) produced 95.85 per cent free from this insect, and the foliage was not injured. Arsenite of zinc powder and arsenite of zinc paste were as effective against the codling moth as arsenate of lead, but considerable foliage injury resulted from their use, about 50 per cent of the leaves being burned on these plats.

Arsenate of zinc, homemade, was effective, but fell somewhat below arsenate of lead in its efficiency. The foliage was not in the least injured from the use of this material.

Arsenates of iron, chemically pure and homemade, did not burn the foliage, but they were only moderately effective against the codling moth. As will be noted from the laboratory feeding tests with this material, its killing effect is slow.

Arsenate of calcium, chemically pure, 0.5 pound to 50 gallons, held the codling moth to 86.88 per cent of fruit free from injury. This fell somewhat below the efficiency of the standard arsenate of lead. However, the use of a slightly increased strength of this material would no doubt have been as effective as arsenate of lead, since it proved to be an effective poison in the laboratory feeding tests. Absolutely no burning resulted from its use, and its sticking qualities were excellent, as was indicated by the abundance of the material that could still be found on the foliage after several hard rains.

Only 38.96 per cent of the fruit from the three trees of the unsprayed plat was free from codling-moth injury.

Experiment V.

Foliage injury tests of various arsenicals and lime-sulphur solution on foliage of peach and bean.

A bean patch was planted in the laboratory yard, August 1, for the purpose of testing the burning effect of the various poisons used in the feeding tests. The leaves were sprayed with a large atomizer August 31. One row containing about 30 plants was used for each poison, one-third of the row being sprayed with the poison alone, one-third with the poison combined with lime at the strength of 2 pounds to 50 gallons of spray, and the remaining third with the poison combined with lime-sulphur, 1½ gallons to 50 gallons of spray. The spray was prevented from blowing to other parts of the row and to other rows by a canvas frame which was placed around the part being sprayed.

An experiment was also conducted on peach foliage on several trees in the laboratory yard. The poisons were used alone in all cases and were applied by means of an atomizer, using one peach limb for each poison. The spray was prevented from reaching other

parts of the tree by the use of a funnel-shaped canvas protector that was placed over the limb being sprayed.

The results of both bean and peach foliage tests are shown in Table V.

TABLE V.—*Tests of the effect of various arsenicals on foliage of bean and peach.*

[Experiment started Aug. 31, 1912, Benton Harbor, Mich. Foliage examined for two weeks.]

INJURY TO BEAN FOLIAGE.

Name and dilution.	Poison used alone.	Poison combined with lime, 2 to 50.	Poison combined with lime-sulphur, 1½ to 50.
Arsenate of lead, di. (powder), 1–50	No burning	No burning	No burning.
Arsenate of lead, tri. (powder), 1–50	do	do	Do.
Arsenate of lead, di. and tri. (powder), 1–50	do	do	Do.
Arsenate of lead, tri. com. paste (1), 2–50	do	do	Do.
Arsenate of lead, tri. com. paste (2), 2–50	Moderate burning	do	Do.
Arsenate of lead, tri. com. paste (3), 2–50	No burning	do	Do.
Arsenate of calcium, c. p. (powder), 1–50	do	do	Do.
Arsenate of iron, c. p. (powder), 2–50	do	do	Do.
Arsenate of iron, h. m., $\frac{8}{10}$–50	do	do	Do.
Arsenate of zinc, c. p. (powder), 1–50	do	do	Do.
Arsenate of zinc, h. m., $\frac{8}{10}$–50	do	do	Do.
Arsenic sulphid, 1–50	Severe burning	Severe burning	Severe burning.
Arsenic tersulphid, ½–50	do	do	Do.
Arsenic trioxid, ½–50	do	Slight burning	Do.
Arsenite of lime, h. m., 2 pts.–50	Moderate burning	No burning	Moderate burning.
Arsenite of zinc, powder (1) c. p., 1–50	Severe burning	do	Severe burning.
Arsenite of zinc (2), com. powder, ¾–50	Moderate burning	do	Moderate burning.
Arsenite of zinc (3), com. paste, 1½–50	do	do	Do.
Arsenite of zinc (4), com. powder, ¾–50	do	do	Do.
Paris green, ½–50	do	Moderate burning	Do.
Lime-sulphur, 1½–50	No burning		

INJURY TO PEACH FOLIAGE.

Name and dilution.	Poison used alone.
Aresenate of lead, di. (powder), 1–50	Very slight burning.
Arsenate of lead, tri. (powder), 1–50	No burning.
Arsenate of lead, di. and tri. (powder), 1–50	Slight burning.
Arsenate of lead, tri. com. paste (1), 2–50	No burning.
Arsenate of lead, tri. com. paste (2), 2–50	Severe burning.
Arsenate of lead, tri. com. paste (3), 2–50	Very slight burning.
Arsenate of calcium, c. p. (powder), 1–50	Moderate burning.
Arsenate of iron, c. p. (powder), 2–50	No burning.
Arsenate of iron, h. m., $\frac{8}{10}$–50	Do.
Arsenate of zinc, c. p. (powder), 1–50	Severe burning.
Arsenate of zinc, h. m., $\frac{8}{10}$–50	Very slight burning.
Arsenic sulphid, 1–50	Severe burning.
Arsenic tersulphid, ½–50	Do.
Arsenic trioxid, ½–50	Do.
Arsenite of lime, h. m., 2 pts.–50	Do.
Arsenite of zinc, powder (1), c. p., 1–50	Do.
Arsenite of zinc (2), com. powder, ¾–50	Do.
Arsenite of zinc (3), com. paste, 1½–50	Do.
Arsenite of zinc (4), com. powder, ¾–50	Do.
Paris green, ½–50	Do.
Lime-sulphur, 1½–50	

Of the arsenates of lead, the diplumbic form had no burning effect on bean foliage and burned peach foliage very slightly. Arsenate of lead, consisting of a mixture of the diplumbic and triplumbic forms, burned peach foliage slightly, but no injury resulted on bean foliage. The commercial No. 1, consisting of the triplumbic form of arsenate of lead, did not injure peach or bean foliage. The commercial (2) burned the peach so badly that all the leaves were shed, and produced

moderate burning on the bean, about 25 per cent of the leaves being shed, but no burning where it was combined with lime or lime-sulphur. The commercial (3) produced no burning on bean foliage and very slight burning on peach foliage.

Arsenate of calcium, c. p., caused about 15 per cent of the leaves to drop on peach, but had no burning effect on bean foliage.

The arsenates of iron, chemically pure and homemade, did not burn either bean or peach foliage.

Arsenate of zinc, c. p., did not burn bean foliage, but seriously injured peach foliage, causing complete defoliation. The homemade form of arsenate of zinc produced very slight burning on peach and no burning on bean foliage.

Arsenic sulphid produced severe burning in all tests.

Arsenic tersulphid produced the same results as arsenic sulphid.

Arsenic trioxid burned severely in all cases except when combined with lime, in which case the burning was slightly less.

Arsenite of lime, homemade, burned the bean foliage moderately when used alone and in combination with lime-sulphur. However, no burning resulted when extra lime was added. The peach foliage was severely burned by this material, causing all the leaves to drop.

Arsenite of zinc (1), chemically pure, burned severely in all cases except where lime was used, in which case no burning resulted.

Arsenite of zinc powder, commercial (2), burned moderately on beans except where lime was added, in which case no burning resulted. It caused all of the peach leaves to drop. Arsenite of zinc, commercial (3) and commercial (4), gave the same results.

Paris green produced moderate burning in all the tests on bean foliage and burned all the leaves off the peach.

EXPERIMENTS, 1913.

LABORATORY TESTS.

Several poisons, namely, arsenate of lead paste, commercial; two commercial brands of powdered arsenate of lead; arsenate of calcium, commercial; two forms of arsenate of calcium, homemade; arsenate of zinc, homemade, and arsenite of zinc, homemade, were tested against the larvæ of several different species of chewing insects.

The arsenates of lead and the arsenite of zinc were used at the strengths recommended by the manufacturers. Arsenate of calcium, commercial paste, was used at the rate of $1\frac{1}{3}$ pounds to 50 gallons of water. Arsenate of zinc, homemade, was prepared and used as given on page 2. Arsenate of calcium (1) was prepared by dissolving 1 pound of sodium arsenate and 1 pound of calcium acetate each in 1 gallon of hot water and pouring them together slowly, at the same time stirring the solution vigorously. This was used at a strength equivalent to 0.8 pound of sodium arsenate to 50 gallons of

water. Arsenate of calcium, homemade (2), was prepared from sodium arsenate and calcium chlorid, the method of procedure being the same as for arsenate of calcium, homemade (1), and was used at the same strength.

Lead chromate, commercial, was used at the rate of 8 pounds to 50 gallons. Lead chromate, homemade, was prepared by dissolving 2 ounces of lead nitrate in one lot of water and 1 ounce of potassium bichromate in another lot of water. The two solutions were then mixed, and a dense yellow precipitate of insoluble lead chromate was formed. The amount of lead chromate formed is 2 ounces, and the strengths at which the material was used in these experiments were based on the amount of lead chromate formed.

H. Maxwell-Lefroy and R. S. Finlow state the following in regard to the use of the above form of homemade lead chromate as an insecticide:[1]

> During this year we have applied this compound to a great variety of crops. We have sprayed them till every leaf was yellow. The poison has remained on for over three weeks, thickly on the leaves, which were uninjured. Sprayed on to crops attacked by caterpillars, the caterpillars are killed, and the results obtained have been excellent. We have used this at 1 pound in 32 gallons. At this strength it is entirely safe, poisons caterpillars, and acts as a very powerful deterrent. * * * Lead chromate has not the poisoning effect of Paris green, for instance, which can be applied at 1 pound in 200 gallons, but it has a poisoning effect comparable with that of lead arsenate, and is, in our experience, a perfect substitute.

As a result of this success with the use of this preparation as an insecticide in India, thorough tests were made with it in experiments conducted during the season of 1913.

Experiment VI.

Arsenate of lead versus arsenate of calcium against larvæ of the tent caterpillar.

In this experiment arsenate of lead paste and the different forms of arsenate of calcium were tested in comparison against newly hatched larvæ of the tent caterpillar. The results of this test are shown in Table VI.

Arsenate of lead alone killed the 50 larvæ in each of the two lots in 5 days, with 0.04 square inch of foliage consumed. Combined with lime-sulphur it required 2 days longer to kill, but only 0.01 square inch of foliage was consumed.

Arsenate of calcium, homemade (1), prepared from sodium arsenate and calcium acetate, killed the larvæ in 5 to 7 days, with 0.05 and 0.06 square inch of foliage consumed when used alone, and in 5 days when combined with lime-sulphur, with 0.02 square inch of foliage consumed. Arsenate of calcium, homemade (2), gave practically the same results.

---

[1] Maxwell-Lefroy, H., and Finlow, R. S. Inquiry into the insecticidal action of some mineral and other compounds on caterpillars. *In* Memoirs Dept. Agr. India, Ent. Ser., v. 4, no. 5, p. 269–327, 1913.

TABLE VI.—*Tests of the killing effect on the tent caterpillar of arsenate of calcium, alone and combined with lime-sulphur, in comparison with arsenate of lead.*

[Experiment started May 17, 1913, Benton Harbor, Mich.; 50 larvæ in each lot.]

Dates of examination.	Check (unsprayed).		Larvæ dying in each lot.											
			Arsenate of lead, 2 to 50.			Arsenate of calcium (homemade, 1), 0.81b. to 50.			Arsenate of calcium (homemade, 2), 0.81b. to 50.			Arsenate of calcium (commercial paste), 1⅓ to 50.		
			Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.
	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Lot 7.	Lot 8.	Lot 9.	Lot 10.	Lot 11.	Lot 12.	Lot 13.	Lot 14.
May 20	1	1	42	45	16	36	38	27	30	33	20	35	43	28
May 22	2	1	8	5	27	12	12	23	18	17	20	15	7	18
May 24	1	0	.....	.....	7	2	.....	.....	2	.....	10	.....	.....	4
May 31	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total number dead	4	2	50	50	50	50	50	50	50	50	50	50	50	50
Days required to kill	.....	.....	5	5	7	7	5	5	7	5	7	5	5	7
Square inches foliage consumed	8.10	6.75	0.04	0.04	0.01	0.05	0.06	0.02	0.04	0.06	0.02	0.06	0.05	0.03

Arsenate of calcium, commercial (paste), used at the rate of 1⅓ pounds to 50 gallons killed all the larvæ in 5 days with 0.05 and 0.06 square inch of foliage consumed. The same preparation combined with lime-sulphur killed in 7 days with 0.03 square inch of foliage consumed.

It will be noted that when lime-sulphur was used with the poison, less foliage was consumed.

EXPERIMENT VII.

LEAD CHROMATE VERSUS ARSENATE OF LEAD AGAINST THE LARVÆ OF FOUR SPECIES OF INSECTS.

Experiments were conducted with lead chromate, commercial and homemade, used at various strengths in comparison with arsenate of lead used at the rate of 2 pounds to 50 gallons of water, against four species of insects, *Eriocampoides cerasi* Peck, *Hyphantria cunea*, *Halisidota caryae* Harris, and *Datana ministra* Drury. The results of these experiments are given in Table VII.

Neither the commercial nor homemade lead chromate was very effective against the pear slug (*Eriocampoides cerasi*), 6 larvæ living through to pupation in each case, and almost as much foliage was consumed as on one of the checks. Arsenate of lead killed 8 of the larvæ in 3 days. The other 2 larvæ escaped. Nine of the larvæ pupated in each of the two unsprayed lots.

TABLE VII.—*Tests of the killing effect on four species of insects of commercial and home-made lead chromate in comparison with arsenate of lead.*

[Benton Harbor, Mich., 1913.]

Name of insect.	Number of larvæ.	Name of material and dilution.	Date experiment started.	Date experiment closed.	Number of observations.	Total larvæ dead.	Number days required to kill.	Square inches foliage consumed.
Eriocampoides cerasi...	10	Check (unsprayed).....	July 2	July 7	5	[1] 1	.....	9.64
	10	.....do.....	...do....	...do....	5	[1] 1	.....	4.36
	10	Arsenate of lead, commercial, 2–50.	...do....	July 5	3	[2] 8	3	0.25
	10	Lead chromate, commercial, 2–50.	...do....	July 7	5	[1] 4	.....	3.48
	10	Lead chromate, homemade, ¾–50.	...do....	...do....	5	[1] 4	.....	3.39
Hyphantria cunea.....	20	Check (unsprayed).....	July 14	July 31	9	4	.....	41.00
	20	.....do.....	...do....	...do....	9	4	.....	37.00
	20	Arsenate of lead, commercial, 2–50.	...do....	July 18	2	20	4	.08
	20	.....do.....	...do....	...do....	2	20	4	.14
	20	Lead chromate, commercial, 8–50.	...do....	July 21	4	20	7	.96
	20	.....do.....	...do....	...do....	4	20	7	.72
	20	Lead chromate, homemade, 1½–50.	...do....	July 23	5	20	9	1.04
	20	.....do.....	...do....	July 21	4	20	7	.88
Halisidota caryæ.....	20	Check (unsprayed).....	...do....	Aug. 1	9	1	.....	3.50
	20	.....do.....	...do....	...do....	9	1	.....	2.20
	20	Arsenate of lead, commercial, 2–50.	...do....	July 18	2	20	4	.30
	20	.....do.....	...do....	...do....	2	20	4	.50
	20	Lead chromate, commercial, 2–50.	...do....	Aug. 1	9	1	.....	3.25
	20	.....do.....	...do....	...do....	9	3	.....	3.50
	20	Lead chromate, homemade, ¾–50.	...do....	...do....	9	1	.....	1.50
	20	.....do.....	...do....	...do....	9	0	.....	1.60
Datana ministra.....	20	Check (unsprayed).....	Aug. 8	Aug. 14	6	1	.....	.....
	20	Arsenate of lead, commercial, 2–50.	...do....	Aug. 10	2	20	2	.....
	20	Lead chromate, commercial, 8–50.	...do....	...do....	2	20	2	.....
	20	Lead chromate, homemade, ¾–50.	...do....	Aug. 14	6	20	6	.....
	20	Lead chromate, homemade, 1½–50.	...do....	Aug. 13	5	20	5	.....
	20	Lead chromate, homemade, 3–50.	...do....	Aug. 10	2	20	2	.....

[1] Remainder pupated. [2] Remainder escaped.

Against the fall webworm (*Hyphantria cunea*) lead chromate, used at the rate of 8 pounds to 50 gallons of water, was effective, although 3 more days were required to kill in this case than in the case of arsenate of lead used at the rate of 2 pounds to 50 gallons of water. The strength of lead chromate in this case is four times greater than was used against the pear slug. Lead chromate, homemade, was used at the rate of 1½ pounds to 50 gallons of water, twice the strength that was used against the pear slug. All the larvæ were killed in 7 to 9 days, which was considerably slower than with arsenate of lead, and considerably more foliage was consumed. Four of the larvæ were dead in each lot of the checks at the end of the experiment, which was closed July 31.

The experiment against *Halisidota caryae* ran for 18 days, at the end of which time the lead chromate, commercial and homemade,

used at the weaker strengths, apparently had no effect on the larvæ. The arsenate of lead killed all the larvæ in 4 days.

For the *Datana ministra*, the commercial lead chromate was used at the rate of 8 pounds to 50 gallons of water, and at this strength the killing effect of the material compared favorably with that of arsenate of lead, 2 pounds to 50 gallons. The lead chromate, homemade, was used at three strengths—$\frac{3}{4}$, $1\frac{1}{2}$, and 3 pounds to 50 gallons of water. The weakest strength killed all the larvæ in 6 days, the next stronger in 5 days. Only one larva had died in the unsprayed lot at the time the experiment was closed, August 14.

Experiment VIII.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE FALL WEBWORM.

Different forms of arsenate of lead, arsenate of calcium, and lead chromate were tested against the larvæ of the fall webworm (*Hyphantria cunea*). Arsenate of zinc and arsenite of zinc were also included in this test, as shown in Table VIII.

Table VIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 23, 1913, Benton Harbor, Mich.; 20 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.												Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.								August.						
		24	25	26	27	28	29	30	31	1	2	3	4			
1	Arsenate of lead paste, commercial, 2-50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	0.42
2	.....do	0	1	1	1	10	6	1	....	....	....	....	....	20	7	.24
3	Arsenate of lead powder, commercial (1), 1-50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	.41
4	.....do	0	0	2	2	10	4	2	....	....	....	....	....	20	7	.22
5	Arsenate of lead powder, commercial (2), 1-50	0	0	1	5	7	7	....	....	....	....	....	....	20	6	.13
6	.....do	0	0	2	1	6	9	2	....	....	....	....	....	20	7	.24
7	Arsenate of calcium paste, commercial, $1\frac{1}{2}$-50	0	1	0	1	10	1	5	2	....	....	....	....	20	8	.75
8	.....do	0	1	1	2	5	3	5	3	....	....	....	....	20	8	.88
9	Arsenate of calcium, homemade (1), $\frac{3}{4}$-50	0	0	0	7	11	2	....	....	....	....	....	....	20	6	.15
10	.....do	0	0	1	3	15	1	....	....	....	....	....	....	20	6	.17
11	Arsenate of calcium, homemade (2), $\frac{3}{4}$-50	0	0	2	2	12	2	2	....	....	....	....	....	20	7	.19
12	.....do	0	0	1	2	12	3	2	....	....	....	....	....	20	7	.12
13	Arsenate of zinc, homemade, $\frac{3}{4}$-50	0	0	0	1	18	1	....	....	....	....	....	....	20	6	.29
14	.....do	0	0	0	1	16	3	....	....	....	....	....	....	20	6	.20
15	Arsenite of zinc powder, commercial, $\frac{3}{4}$-50	0	1	2	7	3	2	4	1	....	....	....	....	20	8	.50
16	.....do	0	1	0	2	8	5	1	3	....	....	....	....	20	8	.79
17	Lead chromate powder, commercial, 8-50	0	0	0	0	1	9	8	2	....	....	....	....	20	8	.84
18	.....do	0	0	0	0	0	5	5	7	1	1	1	....	20	11	2.01
19	Lead chromate, homemade, $1\frac{1}{2}$-50	0	0	0	0	1	6	8	1	2	2	....	....	20	10	1.70
20	.....do	0	0	0	0	0	4	6	1	3	4	1	1	20	12	2.09
21	Check (unsprayed)	0	0	0	0	0	0	0	1	0	0	2	0	3	.....	20.17
22	.....do	0	0	0	0	0	0	0	0	0	0	1	0	1	.....	20.56

Seven days were required to kill the 20 larvæ by arsenate of lead paste, and the two powder forms of arsenate of lead gave almost identical results. Arsenate of calcium, commercial, was one day slower in killing, and slightly more foliage was consumed where this material was used. The two forms of arsenate of calcium, homemade, killed in 6 and 7 days, comparing favorably with the arsenates of lead both in the length of time required to kill and in the amount of foliage consumed. Arsenate of zinc, homemade, killed in 6 days, with 0.20 to 0.29 square inch of foliage consumed. Arsenite of zinc, commercial, required 8 days to kill all the larvæ and 0.79 to 0.84 square inch of foliage was consumed. Lead chromate used at increased strengths was again slow in its killing effect, and more foliage was consumed than in the case of the arsenates. Three larvæ in one lot and one larva in the other lot of unsprayed were dead at the time the experiment was closed August 4. On the two checks 20.17 and 20.56 square inches of foliage were consumed, respectively.

Experiment IX.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE TUSSOCK MOTH.

Three forms of arsenate of lead, three forms of arsenate of calcium, lead chromate (commercial), arsenate of zinc, and arsenite of zinc were tested against larvæ of the tussock moth (*Hemerocampa leucostigma* S. and A.). The experiment was started June 26 and closed July 6, when all the larvæ were dead except in the unsprayed lots. Table IX gives the results of this test.

The three forms of arsenate of lead killed in 4 days, except in one lot of the paste form which required 6 days to kill; the amount of foliage consumed for all the forms varying from 0.01 to 0.08 square inch. Arsenate of calcium, commercial, required on an average more than twice as long to kill as required by arsenate of lead, and considerably more foliage was consumed. The two forms of arsenate of calcium, homemade, killed in slightly less time than was required by the commercial form. Lead chromate, commercial, used at the strength of 8 pounds to 50 gallons of water killed in 6 to 8 days, which was a longer time than required by the ordinary strength of arsenate of lead. Arsenate of zinc, homemade, and arsenite of zinc, commercial, were slower in their killing effect on this insect than was arsenate of lead. Three larvæ were dead in each of two lots of the unsprayed and four dead in the remaining lot, and 5.55 to 7.20 square inches of foliage had been consumed at the time the experiment was closed.

TABLE IX.—*Tests of the killing effect of various poisons on the tussock moth.*

[Experiment started June 26, 1913, Benton Harbor, Mich.; 25 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and larvæ dying in each lot.					Total number dead.	Number days required to kill.	Square inches foliage consumed.
		June.		July.					
		28	30	2	4	6			
1	Arsenate of lead paste, commercial, 2–50	13	12	....	....	....	25	4	0.06
2	.....do	15	10	....	....	....	25	4	.01
3	.....do	11	11	3	....	....	25	6	.08
4	Arsenate of lead powder, commercial (1), 1–50	13	12	....	....	....	25	4	.01
5	.....do	7	18	....	....	....	25	4	.05
6	.....do	18	7	....	....	....	25	4	.02
7	Arsenate of lead powder, commercial (2), 1–50	10	15	....	....	....	25	4	.07
8	.....do	16	9	....	....	....	25	4	.04
9	.....do	17	8	....	....	....	25	4	.02
10	Arsenate of calcium paste, commercial, 1½–50	4	11	1	5	4	25	10	.50
11	.....do	2	3	7	13	....	25	8	.68
12	.....do	5	8	10	2	....	25	8	.42
13	Arsenate of calcium, homemade (1), 0.8–50	9	7	4	2	3	25	10	.20
14	.....do	10	7	4	4	....	25	8	.38
15	.....do	6	15	4	....	....	25	6	.15
16	Arsenate of calcium, homemade (2), 0.8–50	10	6	1	0	5	25	10	.10
17	.....do	4	17	3	1	....	25	8	.23
18	.....do	17	7	1	....	....	25	6	.06
19	Lead chromate, commercial, 8–50	0	9	16	....	....	25	6	.55
20	.....do	0	6	16	3	....	25	8	.20
21	.....do	0	5	20	....	....	25	6	.18
22	Arsenate of zinc, homemade, 0.8–50	10	10	1	4	....	25	8	.46
23	.....do	12	9	1	3	....	25	8	.38
24	.....do	5	15	0	5	....	25	8	.62
25	Arsenite of zinc powder, commercial, ¾–50	8	15	0	1	1	25	10	.60
26	.....do	6	9	8	2	....	25	8	.74
27	.....do	8	8	3	6	....	25	8	.72
28	Check (unsprayed)	0	1	0	0	2	3	.....	5.80
29	.....do	0	0	0	3	0	3	.....	7.20
30	.....do	0	2	0	2	0	4	.....	5.55

EXPERIMENT X.

FIELD TESTS OF VARIOUS ARSENICALS AGAINST THE CODLING MOTH, 1913.

Field tests were made with the following preparations against the codling moth on apple: Arsenate of lead paste, commercial; arsenate of calcium paste, commercial; arsenate of calcium, homemade, prepared from sodium arsenate and calcium acetate; arsenate of calcium, homemade, prepared from sodium arsenate and calcium chlorid; arsenite of zinc powder, commercial; and arsenate of zinc, homemade. (For methods of preparation of the homemade materials, see p. 2.) All the materials were used in combination with lime-sulphur, 1½ to 50. The spraying was done in Mr. J. T. Beckwith's orchard in the vicinity of Benton Harbor, Mich., the same orchard that was used for the experimental work of the previous season. The results of this experiment are shown in Table X.

TABLE X.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1913.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons of lime-sulphur solution	1	129	2,144	2,273	94.32
		2	132	2,490	2,622	94.96
		3	135	2,244	2,379	94.32
		4	157	1,850	2,007	92.17
		5	125	1,927	2,052	93.90
	Plat total		**678**	**10,655**	**11,333**	**94.01**
II	Arsenate of calcium, homemade (1), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	398	2,767	3,165	87.42
		2	208	1,443	1,651	87.40
		3	180	740	920	80.43
		4	254	720	974	73.92
		5	331	976	1,307	74.67
	Plat total		**1,371**	**6,646**	**8,017**	**82.89**
III	Arsenate of calcium, homemade (2), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	580	2,607	3,187	81.80
		2	388	897	1,285	69.80
		3	497	1,195	1,692	70.62
		4	387	955	1,342	71.16
		5	260	600	860	69.76
	Plat total		**2,112**	**6,254**	**8,366**	**74.75**
IV	Arsenate of calcium, commercial (paste), 1½ pounds to 50 gallons lime-sulphur solution	1	251	813	1,064	76.41
		2	241	918	1,159	79.20
		3	53	277	330	83.94
		4	240	681	921	73.94
		5	303	1,025	1,328	77.18
	Plat total		**1,088**	**3,714**	**4,802**	**77.34**
V	Arsenite of zinc powder, ¾ pound to 50 gallons lime-sulphur solution	1	241	2,345	2,586	90.68
		2	83	978	1,061	92.17
	Plat total		**324**	**3,323**	**3,647**	**91.11**
VI	Arsenate of zinc, homemade, at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	365	2,342	2,707	86.51
		2	503	1,867	2,370	78.78
		3	376	1,731	2,107	82.15
		4	213	1,386	1,599	86.68
		5	186	1,951	2,137	91.92
	Plat total		**1,643**	**9,277**	**10,920**	**84.95**
VII	Check (unsprayed)	1	927	877	1,804	48.61
		2	670	503	1,173	42.88
		3	1,082	1,086	2,168	50.01
		4	606	592	1,198	49.41
		5	933	780	1,713	45.53
	Plat total		**4,218**	**3,838**	**8,056**	**47.64**

The arsenate of lead plat produced 94.01 per cent of fruit free from codling-moth injury. Arsenate of calcium, homemade (1), fell below this in its efficiency, the percentage of sound fruit being 82.89. Arsenate of calcium, homemade (2), fell still lower in efficiency, producing 74.75 per cent of fruit free from this insect. Each of these materials burned the foliage very slightly. Arsenate

of calcium, commercial, produced 77.34 per cent of sound fruit, about an average of the efficiency of the two homemade preparations. The slight burning effect on the foliage amounted to about the same as on the homemade arsenate of calcium plats. Arsenite of zinc powder, commercial, produced 91.11 per cent sound fruit. This material produced moderate burning, about 20 per cent of the leaves being more or less spotted by the spray. Arsenate of zinc, homemade, produced no burning of the foliage and held the codling moth to 84.95 per cent free from worms. The unsprayed plat averaged 47.64 per cent of fruit free from codling-moth injury.

EXPERIMENTS, 1914.

Experiments with various insecticides, alone and combined with fungicides, were made, both at the laboratory and in the field, during the season of 1914. The investigations were continued along the same lines as during the two previous seasons.

The field experiments were conducted in the J. T. Beckwith apple orchard, the John Hamilton pear orchard, both of Benton Harbor, Mich., and the William Birkit vineyard, located at Glenlord, Mich. The field experiments were on a relatively large scale, so that the results represent what may be expected on a commercial basis.

LABORATORY TESTS.

The fall webworm (*Hyphantria cunea* Drury) was not so abundant as during the seasons of 1912 and 1913, and it was not always possible to secure a sufficient number of young larvæ for the poison-feeding tests. Consequently, when larger larvæ were used, the strength of the poisons was increased to accelerate the killing of the larvæ. However, the same size of larva was used in all lots in each experiment, and the results are therefore comparative.

The laboratory experiments included commercial and homemade insecticides, used alone or combined with a fungicide. Wild-cherry twigs were sprayed by means of a hand atomizer and the spray material allowed to dry thoroughly before placing the larvæ upon the host plant. Time did not permit daily observations, and accordingly the results do not always represent close comparisons, but from a practical point of view they are sufficient.

Experiment XI.

VARIOUS ARSENICALS ALONE AND COMBINED WITH OIL EMULSIONS AGAINST LARVÆ OF THE FALL WEBWORM.

The chief object of this experiment was to ascertain whether the combining of arsenate of lead with kerosene emulsion would affect the individual value of either material for insecticidal purposes.

Other arsenicals, namely, commercial arsenite of zinc and commercial arsenate of calcium, were likewise tested. The results are given in Table XI.

TABLE XI.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 17, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		23	29	7	13			
1	Kerosene emulsion, 10 per cent	0	0	0	0	0	.....	61.00
2	Arsenate of lead powder, 1½–50 + kerosene emulsion, 10 per cent	10	....	....	....	10	6	0.36
3	Arsenite of zinc powder, 1⅛–50 + kerosene emusion, 10 per cent	10	....	....	....	10	6	0.20
4	Arsenate of calcium, commercial powder, 1½–50 + kerosene emulsion, 10 per cent	0	3	6	1	10	27	13.50
5	Anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
6	Arsenate of lead powder, 1½–50 + anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
7	Arsenate of lead powder, 1½–50	10	....	....	....	10	6	0.14
8	Arsenite of zinc powder, 1⅛–50	10	....	....	....	10	6	0.04
9	Arsenate of calcium, commercial powder, 1½–50	10	....	....	....	10	6	0.48
10	Check (unsprayed)	0	0	0	0	0	.....	53.00

[1] Foliage badly burned—unfit for consumption.

Kerosene emulsion alone, at a 10 per cent strength, had no poisonous effect upon the fall webworm larvæ—at least none had been killed after having fed for a period of 27 days, with a consumption of 61 square inches of foliage. The arsenate of lead alone killed the 10 larvæ in 6 days—foliage consumed, 0.14 square inch. A combination of these insecticides also caused the death of all the larvæ in 6 days after 0.36 square inch of foliage had been eaten. The other arsenicals, alone or combined with the emulsion (except arsenate of calcium combined), likewise killed in 6 days after a relatively small amount of foliage had been consumed. Arsenate of calcium powder, used alone, was quite as effective as the other arsenicals, but in combination with the emulsion 27 days were required to kill the larvæ, which consumed 13.50 square inches of foliage. A similar result was obtained in a later experiment. (See Experiment XIII.) Anthracene emulsion, 10 per cent, alone and combined with arsenate of lead, burned the foliage badly, rendering it unpalatable.

As shown in Experiment XV, kerosene emulsion, 10 per cent, combined with arsenate of lead is also an effective aphidicide. Although there is some breaking down of the materials in combination, no injury to the foliage was noted in the laboratory tests.

Experiment XII.

COMBINED SPRAYS AGAINST LARVÆ OF THE FALL WEBWORM.

The purpose of Experiment XII was to test by the laboratory method certain spray combinations, some of which were being used under field conditions. The arsenate of calcium used in this experiment was prepared by using 4 pounds of stone lime, to which was added 18 ounces of sodium-arsenate crystals during the slaking. This, when mixed with the proper quantity of water, was used for the making of Bordeaux mixture 4–4–50. This combination was made with a view to using it as a vineyard spray. The results of this experiment appear in Table XII.

Table XII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 24, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		29	1	7	13			
1	Arsenate of lead powder, 1½–50+lime-sulphur, 1½–50	7	3	....	....	10	8	0.18
2	Lime-sulphur, 1½–50	5	1	4	....	10	14	0.82
3	Arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.46
4	Commercial sodium sulphid, 2–50	2	4	3	1	10	20	3.34
5	Commercial sodium sulphid, 2–50+arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.22
6	Commercial barium tetrasulphid, 5–50	4	0	5	1	10	20	5.76
7	Commercial barium tetrasulphid, 5–50+arsenate of lead powder, 1½–50	3	6	1	....	10	14	0.34
8	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50	8	2	....	....	10	8	0.10
9	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50+nicotine sulphate, 40 per cent, 1–1,600	5	5	....	....	10	8	0.10
10	Check (unsprayed)	1	1	0	0	2	.....	13.50

As will be noted in Table XII, arsenate of lead, either alone or combined with lime-sulphur solution or commercial sodium sulphid, killed all the larvæ in 8 days. The same arsenical combined with commercial barium tetrasulphid compound required 14 days to kill the 10 larvæ, although 9 of these were recorded dead at the end of the eighth day. The arsenate of calcium made in the same operation of slaking the stone lime for Bordeaux mixture caused the death of all the larvæ in 9 days. This combination was tested in a vineyard and caused no foliage injury. At the end of 20 days, when the experiment was closed, but two larvæ of the unsprayed lot were dead.

Experiment XIII.

ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD, ALONE AND COMBINED WITH KEROSENE EMULSION AND WITH LIME-SULPHUR SOLUTION AGAINST LARVÆ OF THE FALL WEBWORM.

In this experiment a comparative test was made with homemade arsenate of calcium at several strengths, commercial arsenate of calcium, paste and powder, and other materials.

The homemade arsenate of calcium used in this and succeeding experiments was prepared by adding sodium-arsenate crystals to stone lime during the course of slaking.

Formula 1.—Stone lime, 1 pound; sodium arsenate, ½ pound; water, 1½ quarts. This formula, according to chemical analysis, gave a total arsenic oxid (As_2O_5) content of 4.19 per cent; no soluble arsenic oxid.

Formula 2.—Stone lime, 3 pounds; sodium arsenate, 3 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 6.16 per cent, no soluble arsenic oxid.

Formula 3.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 3.93 per cent; no soluble arsenic oxid.

Formula 4.—Stone lime, 4 pounds; sodium arsenate, 1 pound; water, 5 quarts; analysis—total arsenic oxid (As_2O_5), 1.88 per cent; no soluble arsenic oxid.

Formula 5.—Stone lime, 3 pounds; sodium arsenate, 1 pound; water, 3 quarts; analysis—total arsenic oxid (As_2O_5), 2.92 per cent; no soluble arsenic oxid.

Formula 6.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; slaking not vigorous; not analyzed.

In all of the homemade formulas lime has been used in considerable excess, with a corresponding decrease of the arsenical content. The commercial arsenate of calcium, paste, showed an analysis of 18.82 per cent total arsenic oxid—soluble arsenic oxid, a trace.

With a view to making a combination spray for peaches and other stone fruits, arsenate of calcium was prepared in the same operation with the making of self-boiled lime-sulphur (8–8–50 formula). As soon as the lime started to slake, 2 pounds of sodium-arsenate crystals and then the sulphur were added and the mixture made up in the usual way. Arsenate of calcium made with self-boiled lime-sulphur may be of value as a spray for stone fruits, owing to the fact that the large excess of lime would tend to prevent burning. Arsenate of calcium, alone, causes injury to peach foliage, unless there is an excess of lime. The calcium on exposure to the atmosphere gradually combines with the carbon dioxid of the air and becomes calcium carbonate, thus releasing some soluble arsenic. For the results of this experiment, see Table XIII.

Arsenate of lead alone killed all larvæ in 8 days; combined with kerosene emulsion, 10 per cent, in 6 days (see Experiment XI); with lime-sulphur in 6 days, and with self-boiled lime-sulphur in 8 days. Commercial arsenate of calcium, powder, required 8 days to kill. Commercial arsenate of calcium, paste, required 27 days, but when combined with lime-sulphur solution, killed in 10 days.

TABLE XIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 14, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.													Total number dead.	Number days required to kill.	Square inches foliage consumed.
		August—							September—								
		18	20	22	24	26	28	31	2	5	8	10	14	19			
1	Arsenate of lead paste, 4–50	3	6	1											10	8	(1)
2	Arsenate of calcium (commercial) paste, 4–50	0	0	0	2	1	0	1	2	1	2	1			10	27	29.84
3	Arsenate of calcium (commercial) powder, 2–50	1	6	3											10	8	1.00
4	Arsenate of calcium paste (homemade, formula 1), 4–50	1	0	1	4	1	1	1	0	0	1				10	25	6.25
5	Arsenate of calcium paste (homemade, formula 1), 4–50	0	0	4	2	1	0	0	0	0	0	1	1	0	9		15.50
6	Arsenate of calcium paste (homemade, formula 2), 4–50	0	0	1	7	1	1								10	14	6.00
7	Arsenate of calcium paste (homemade, formula 2), 2½–50	0	0	0	0	1	0	1	0	2	1	1	0	1	7		33.00
8	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	1	2	0	0	0	0	0	0	1	2	1	7		48.00
9	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	3	0	0	0	1	2	4					10	22	17.00
10	Arsenate of calcium paste (homemade, formula 4), 4–50	0	0	0	0	0	0	0	0	0	0	4	1	4	9		61.50
11	Arsenate of calcium paste (homemade, formula 4), 10–50	0	0	2	0	0	2	0	1	1	3	0	0	0	9		22.00
12	Arsenate of calcium paste (homemade, formula 5), 4–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0		114.00
13	Arsenate of calcium paste (homemade, formula 5), 6–50	0	0	3	1	1	0	0	0	0	0	1	0	2	8		18.50
14	Arsenate of calcium paste (homemade, formula 6), 4–50 Slaking, not vigorous	0	2	1	2	0	0	2	2	1					10	22	13.00
15	Arsenate of calcium paste (homemade, formula 6), 4–50. Slaking, not vigorous	1	0	2	4	2	1								10	14	5.28
16	Arsenate of lead paste, 4–50+kerosene emulsion, 10 per cent	5	5												10	6	.80
17	Arsenate of calcium paste, commercial, 4–50+kerosene emulsion, 10 per cent	0	0	1	0	0	0	0	0	0	2	0	0	1	4		38.00
18	Arsenate of calcium paste (homemade, formula 3)+kerosene emulsion, 10 per cent	0	0	4	2	0	0	1	0	0	2	0	0	0	9		38.00
19	Kerosene emulsion, 10 per cent	0	0	0	0	0	0	0	0	0	0	0	0	0	0		72.00
20	Arsenate of lead paste, 4–50+lime-sulphur, 1½–50	6	4												10	6	.31
21	Arsenate of calcium (commercial) paste, 4–50+lime-sulphur, 1½–50	0	0	1	9										10	10	2.00
22	Arsenate of calcium (homemade, formula 3)+lime-sulphur, 1½–50	0	1	1	5	2	1								10	14	4.50
23	Sodium arsenate (crystals technically pure), 2 pounds+self-boiled lime-sulphur, 8–8–50	0	0	4	6										10	10	8.00
24	Arsenate of lead paste, 4–50+self-boiled lime-sulphur, 8–8–50	1	8	1											10	8	.56
25	Check (unsprayed)	0	0	0	0	0	0	0	0	0	0	0	1	0	1		72.00

[1] Not measured.

The homemade arsenate of calcium products, as noted previously, were low in arsenic oxid content, but as a whole proved relatively effective as poisoning agents. Formula (2), arsenic oxid 6.16 per cent, at the rate of 4 to 50, required 14 days, which was the same length of time required by formula (3), arsenic oxid 3.93 per cent, 4 to 50, combined with lime-sulphur solution. The arsenate of calcium prepared along with self-boiled lime-sulphur killed all larvæ in 10 days. The experiment was closed at the end of 36 days, only one larva of the unsprayed lot having died.

Experiment XIV.

ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD, ALONE AND COMBINED WITH LIME-SULPHUR SOLUTION, AGAINST LARVÆ OF THE FALL WEBWORM.

Homemade arsenate of calcium was again tested in comparison with commercial arsenate of calcium (paste and powder) and arsenate of lead, paste. These arsenicals were used alone and combined with lime-sulphur solution, 1½ to 50. The results of this experiment will be found in Table XIV.

Table XIV.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 27, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.								Total number dead.	Number days required to kill.	Square inches foliage consumed.
		Aug. 31.	September—									
			2	5	8	10	14	16	19			
1	Arsenate of lead paste, 3–50	0	0	6	4	....	....	....	....	10	12	3.00
2	.....do	0	0	9	1	....	....	....	....	10	12	3.00
3	Arsenate of lead paste, 3–50+lime-sulphur, 1½–50	0	1	6	2	1	....	....	....	10	14	2.25
4	.....do	0	0	7	2	1	....	....	....	10	14	.25
5	Arsenate of lead paste, 5–50	0	0	8	2	....	....	....	....	10	12	2.50
6	.....do	1	2	5	2	....	....	....	....	10	12	3.50
7	Arsenate of lead paste, 5–50+lime-sulphur, 1½–50	0	1	5	4	....	....	....	....	10	12	.50
8	.....do	0	0	3	4	3	....	....	....	10	14	1.50
9	Arsenate of calcium, commercial paste, 5–50	0	0	0	0	0	3	0	1	4	.....	63.00
10	.....do	0	0	0	0	4	1	1	0	6	.....	38.00
11	Arsenate of calcium, commercial paste, 5–50+lime-sulphur, 1½–50	0	0	3	4	3	....	....	....	10	14	13.50
12	.....do	0	1	1	6	2	....	....	....	10	14	3.75
13	Arsenate of calcium, commercial powder, 2½–50	0	0	0	7	3	....	....	....	10	14	10.50
14	.....do	0	1	2	0	3	4	....	....	10	18	20.05
15	Arsenate of calcium, commercial powder, 2½–50+lime-sulphur, 1½–50	1	0	3	2	4	....	....	....	10	14	4.00
16	.....do	0	1	4	5	....	....	....	....	10	12	1.75
17	Arsenate of calcium (homemade paste, formula 1), 5–50	0	0	0	0	2	1	0	0	3	.....	42.00
18	.....do	0	0	0	0	3	0	0	2	5	.....	27.50
19	Arsenate of calcium (homemade paste, formula 1), 5–50+lime-sulphur, 1½–50	0	0	4	4	0	2	....	....	10	18	9.25
20	.....do	0	0	2	4	3	0	1	....	10	20	10.00
21	Arsenate of calcium (homemade paste, formula 3), 5–50	0	0	0	0	1	1	1	0	3	.....	63.00
22	.....do	0	0	0	0	0	0	0	0	0	.....	72.25
23	Arsenate of calcium (homemade paste, formula 3), 5–50+lime-sulphur, 1½–50	0	3	0	1	0	6	....	....	10	18	19.50
24	.....do	0	0	3	3	4	....	....	....	10	14	17.00
25	Lime-sulphur, 1½–50	0	3	2	1	3	0	1	....	10	20	8.00
26	.....do	0	1	3	2	4	....	....	....	10	14	1.25
27	Check (unsprayed)	1	0	0	0	0	0	0	0	1	.....	81.00
28	.....do	1	1	0	1	2	0	0	0	5	.....	69.25

As will be noted in Table XIV, arsenate of lead as usual killed the larvæ more quickly than any of the other arsenicals. Arsenate of lead paste at the rate of 3 to 50 or 5 to 50 required 12 days to kill all of the larvæ; when combined with lime-sulphur it required slightly longer with a decreased amount of feeding.

As shown in the preceding experiments of 1914, commercial arsenate of calcium when combined with lime-sulphur is a relatively effective poison. Likewise, in this experiment, both lots of the paste form in combination with lime-sulphur killed in 14 days; the powdered form mixed with lime-sulphur in 14 and 12 days.

The homemade arsenate of calcium compounds, when employed with lime-sulphur, were also relatively effective, especially when their low arsenical content is taken into consideration. Homemade arsenate of calcium, formula 1 ($As_2O_5 = 4.19$ per cent), plus lime-sulphur, was effective in killing all the larvæ of both lots in 18 and 20 days. Homemade arsenate of calcium, formula 3 ($As_2O_5 = 3.93$ per cent), required 18 and 14 days.

Experiment XV.

Comparison of the killing effect of various contact poisons on Aphis pomi.

A series of laboratory tests was made with various contact insecticides, alone and combined with other materials, against the green apple aphis (*Aphis pomi* De G.). Apple twigs well infested with this species were thoroughly sprayed and then placed in separate glasses containing water. The results were taken one day after date of application. Four tests were made, namely, (1) August 20, p. m.; (2) August 21, a. m.; (3) August 21, p. m.; and (4) September 17. For test (1) all the materials were freshly combined except No. 17, which had been mixed several days previous to its application. The spray materials used in tests (2) and (3) were the same as those employed in test (1), except that they had stood mixed about 18 and 24 hours, respectively, before usage. The chief object of tests (2) and (3) was to ascertain whether or not the mixing of these materials some time in advance of their use would affect their insecticidal value. In test (4) a bucket pump was used for applying the spray, a hand atomizer being used in the other three tests. The results of this experiment appear in Table XV.

TABLE XV.—*Aphis pomi, contact insecticide experiments.*

[Benton Harbor, Mich., 1914.]

Lot No.	Name and dilution.	Per cent of aphides killed.			
		Test 1, Aug. 20, p. m.	Test 2, Aug. 21, a. m.	Test 3, Aug. 21, p. m.	Test 4, Sept. 17.
1	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800	100	100	100	.....
2	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
3	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,200+laundry soap, 3–50	.....	.....	.....	100
4	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,600+laundry soap, 3–50	.....	.....	.....	100
5	Nicotine sulphate (Com. No. 1), 40 per cent, 1–2,000+laundry soap, 3–50	.....	.....	.....	100
6	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	.....
7	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+laundry soap, 3–50	100	100	100	.....
8	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800	100	100	100	.....
9	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	.....
10	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
11	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50+arsenate of lead paste, 2–50	100	100	100	.....
12	Kerosene emulsion (66 per cent stock), 1 per cent	.....	.....	.....	0
13	Kerosene emulsion (66 per cent stock), 3 per cent	.....	.....	.....	35
14	Kerosene emulsion (66 per cent stock), 5 per cent	.....	.....	.....	100
15	Kerosene emulsion (66 per cent stock), 10 per cent	100	100	100	100
16	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	100	100	100	.....
[1]17	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	[2] 95	[2] 98	[2] 98	.....
18	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	.....
19	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	.....
20	Anthracene emulsion (66 per cent stock), 5 per cent	[3] 100	[3] 100	[3] 100	.....
21	Anthracene emulsion (50 per cent stock), 3 per cent	.....	.....	.....	100
22	Anthracene emulsion (50 per cent stock), 1 per cent	.....	.....	.....	75
23	Laundry soap, 3–50	[4] 75	[4] 75	[4] 75	15
24	Laundry soap, 5–50	.....	.....	.....	50
25	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	.....
26	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	.....
27	Arsenate of lead paste, 2–50	0	[5] 10	0	.....
28	Naphtha soap, 3–50	.....	.....	.....	0
29	Naphtha soap, 5–50	.....	.....	.....	0
30	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 10 per cent	.....	.....	.....	85
31	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 5 per cent	.....	.....	.....	50
32	Kerosene emulsion (naphtha soap, cold water), 10 per cent	.....	.....	.....	100
33	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 3 per cent	.....	.....	.....	100
34	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 1 per cent	.....	.....	.....	25
35	Fish-oil soap, 3–50	.....	.....	.....	10
36	Fish-oil soap, 5–50	.....	.....	.....	90
37	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,200+laundry soap, 3–50	.....	.....	.....	100
38	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,600+laundry soap, 3–50	.....	.....	.....	100
39	Nicotine sulphate (Com. No. 2), 40 per cent, 1–2,000+laundry soap, 3–50	.....	.....	.....	100
40	Check (unsprayed)	0	0	0	0

[1] Stood combined several days before usage.
[2] A few adults not killed.
[3] Foliage severely burned.
[4] Adult aphides not killed.
[5] No adult aphides killed.

As will be noted in Table XV, the majority of the materials proved effective aphidicides. Thus it will be seen that several combinations may be used with good effect when it is aimed to control both chew-

ing and sucking insects at the same time. It would appear that it is not well to allow kerosene emulsion and arsenate of lead to stand combined too long previous to its application, if the best results are to be obtained. However, a standing for a day or so would make no material difference, since there is but slight breaking down of the soap. In general, insecticides should not be combined until they are to be used. Anthracene emulsion, 5 per cent, burned the foliage badly. Laundry soap, 3 to 50, was effective against the young aphides only. Arsenate of lead alone, as was to be expected, had little or no effect upon the aphides. The combination of arsenate of calcium with kerosene emulsion is not a desirable one, since an insoluble calcium soap is formed, thereby releasing some free kerosene.

According to the results of the above experiment a 10 per cent kerosene emulsion should prove effective against the green apple aphis. In one instance, however, not all of the aphides were killed. The nicotine solutions, with a dilution up to 1 to 2,000 combined with soap, were likewise effective aphidicides. Anthracene emulsion, 3 per cent, gave satisfactory control, and at this strength caused no foliage injury. The kerosene emulsions under 10 per cent were not satisfactory, neither were the soaps at the strengths tested, except that fish-oil soap, 5 to 50, killed 90 per cent of the aphides.

FIELD EXPERIMENTS.

POISON TESTS IN EXPERIMENTAL APPLE ORCHARD.

The Ben Davis orchard which had been used for experimental purposes during the seasons of 1912 and 1913 was again secured for continued investigations. The orchard was in very fair condition and responded very creditably in fruit production, the crop in 1914 being larger than any produced in the past. The experiments included tests of insecticides combined with fungicides, since, in commercial orcharding, a combination spray is usually made. Most of the plats received five spray applications, namely: (1) Dormant application, April 16 and 17; (2) cluster-bud stage, May 5 and 6; (3) when petals dropped, May 23, 25, and 26; (4) three to four weeks later, June 15, 16, and 17; (5) nine weeks after petals dropped, July 27 and 28. The orchard was sprayed with a power outfit having a pressure averaging about 225 pounds.

The results of the investigations as reported in the succeeding pages were obtained from an examination of the fruit. Certain trees in each plat are designated as count trees. The dropped fruit from the count trees was picked up and examined weekly throughout the season, and at harvesting time the picked fruit was likewise examined. The more important results of the experiments for the control of the codling moth are herewith reported.

Experiment XVI.

Field tests of arsenate of calcium versus arsenate of lead against the codling moth, 1914.

One of the most promising of the insecticides tested during the season of 1914 was an arsenate of calcium paste. A commercial article was employed at the rate of 2 pounds to each 50 gallons of lime-sulphur solution. The plat sprayed with this material consisted of 12 trees, the fruit from five of which was examined throughout the season. The plat sprayed with arsenate of lead paste, 2 pounds combined with 50 gallons lime-sulphur solution, included 12 trees, the fruit from six of which was examined. Plats III, IV, and V, located in different parts of the orchard, were left unsprayed as a check. These plats had a total of eight trees, all of which were examined. Three applications were given Plats I and II, for the control of the codling moth: (1) When petals dropped; (2) three to four weeks later; (3) nine weeks after petals dropped, for the control of the second brood.

The arsenate of calcium paste was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

Analysis of arsenate of calcium (paste).

	Per cent.
Moisture	55.80
Total arsenic oxid, As_2O_5	18.82
Total calcium oxid, CaO	17.93
Total lead oxid, PbO	3.72
Soluble impurities, exclusive of PbO and As_2O_5	1.84
Water of constitution and undetermined (small amount of CO_2)	1.89
Total	100.00
Soluble arsenic	Trace.

This sample contains lead equivalent to approximately 5.5 per cent lead arsenate. The results of this experiment are shown in Table XVI.

Table XVI.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. A comparison of arsenate of calcium with arsenate of lead. Benton Harbor, Mich., 1914.]

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of calcium (commercial paste), 2 pounds to 50 gallons lime-sulphur solution.	1	123	8,087	8,210	98.50
		2	78	5,424	5,502	98.58
		3	47	4,988	5,035	99.06
		4	44	6,132	6,176	99.43
		5	63	4,283	4,346	98.56
	Plat total		355	28,914	29,269	98.79

TABLE XVI.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
II.....	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total.....	.....	**134**	**23,884**	**24,018**	**99.44**
III-V..	Checks (unsprayed).....	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total.....	.....	**19,764**	**28,102**	**47,866**	**58.71**

As will be noted in Table XVI, out of 29,269 apples from the plat sprayed with arsenate of calcium 98.79 per cent were free from codling moth. The fruit examined on Plat II, 24,018 apples, sprayed with arsenate of lead, was 99.44 per cent free from the codling moth. The unsprayed trees yielded 47,866 apples, of which but 58.71 per cent were free from worms.

It will thus be seen that the arsenate of calcium compared very favorably with the arsenate of lead, and since it can be produced more cheaply than the lead arsenate it would appear to have distinct value. The foliage in Plat I was as healthy appearing as in Plat II throughout the season, and, further, the fungicidal value of lime-sulphur was practically the same, whether arsenate of calcium or arsenate of lead was used. While arsenate of calcium has not been sufficiently tested to recommend it for general use, yet it would seem that this arsenical will probably serve as a satisfactory and cheap substitute for arsenate of lead. Arsenate of calcium may be manufactured either in the paste or powdered form or made at home in the paste form.

HOMEMADE ARSENATE OF CALCIUM.

Arsenate of calcium may be prepared at home from various chemicals, the more important being arsenic acid and lime, sodium arsenate and calcium chlorid, sodium arsenate and calcium acetate, etc. Potassium dihydrogen arsenate may be substituted for the sodium arsenate, but is more expensive and would have no distinct advantages over the latter.

The logical way to make arsenate of calcium is by combining arsenic acid with lime, but at the present writing arsenic acid can

not be obtained on the market to advantage. In view of this fact arsenate of calcium may be prepared at home by combining fused (dry powdered) sodium arsenate with lime. The by-product is largely sodium hydroxid, most of which may be decanted. It is possible that decantation will not be necessary when the arsenate of calcium is to be applied to foliage that is not too tender. The formula for making is herewith given:

Stone lime (90 per cent CaO)	pounds..	55
Sodium arsenate, fused (dry powdered) 65 per cent As_2O_5	do....	100
Water	gallons..	26

Place the stone lime in a wooden container and add a small amount of water, just enough to start slaking. When slaking is well under way pour in the sodium arsenate, which should first have been dissolved in hot water. Keep stirring until the lime has thoroughly slaked. Sufficient water should be added from time to time to prevent burning.

The resulting arsenate of calcium should contain about 18 per cent of arsenic oxid. In making this compound it will of course be necessary to know approximately the calcium oxid and arsenic oxid content of the materials employed and to vary the formula accordingly.

Arsenate of calcium was prepared at the laboratory in the proportions as given below:

Stone lime[1] (80 per cent CaO)	pounds..	6
Sodium arsenate,[2] fused (dry powdered) 62 per cent As_2O_5	do....	10
Water	gallons..	2

The above was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

	Per cent.
Moisture	46.90
Total arsenic oxid, As_2O_5	20.37
Total arsenious oxid, As_2O_3	.21
Calcium oxid, CaO	18.95
Carbon dioxid, CO_2	.18
Undetermined, mainly sodium hydrate	13.39
Total	100.00
Soluble arsenic oxid, As_2O_5	.04

Experiment XVII.

Field tests of powdered arsenate of lead versus paste arsenate of lead against the codling moth, 1914.

Since the advent of the powdered form of arsenate of lead the question has naturally arisen as to whether this newer form of the arsenical is as effective as the older or paste form. The powdered arsenate of lead has been on the market for several years and is now being recommended by several manufacturers, who claim for it

[1] This lime was not well burned, since it contained considerable calcium carbonate.

[2] Sodium arsenate, fused (dry powdered) $Na_2H\ AsO_4$. As_2O_5=61.86 per cent; As_2O_3=1.42 per cent.

certain advantages. The principal points given in favor of the powder over the paste are that it can be more conveniently mixed, that the proper amount to be used for each spray tank may be weighed out with a greater degree of accuracy, and that it can be stored more readily without deterioration. There is also a distinct saving in freight. For the advantages enumerated the fruit grower is asked to pay a trifle more in price, since it costs the manufacturer somewhat more to produce the powdered form.

With this in view, experiments were conducted to test the efficiency of the powdered form in comparison with the paste. Since the powdered arsenical has approximately twice the strength of the paste, one-fourth pound of the powder was directly compared with one-half pound of the paste, one-half pound of the powder was compared with 1 pound of the paste, and 1 pound of the powder was compared with 2 pounds of the paste. All of these were combined with 50 gallons of lime-sulphur solution, with the exception of Plat IV, where a commercial precipitated sulphur was employed.

Three spray applications against the codling moth were made: (1) when petals dropped; (2) 3 to 4 weeks later; (3) 9 weeks after petals dropped for second-brood larvæ.

The dropped fruit from certain count trees in each plat was picked up weekly and examined. The fruit gathered at harvest time was likewise examined and the results recorded.

Plat I consisted of 9 trees, the fruit from 5 of which was examined; Plat II, 9 trees, 5 examined; Plat III, 4 trees, 3 examined; Plat IV, 5 trees, 3 examined; Plat V, 9 trees, 5 examined; Plat VI, 7 trees, 5 examined; Plat VII, 12 trees, 6 examined; Plats VIII, IX, and X, total 8 trees, 8 examined. For the results of this experiment see Table XVII.

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Benton Harbor, Mich., 1911. Poison test. Comparison of arsenate of lead in powdered and paste form.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (powder), ¼ pound to 50 gallons lime-sulphur solution	1	28	667	695	95.97
		2	16	1,036	1,052	98.48
		3	155	3,052	3,207	95.17
		4	117	1,650	1,767	93.38
		5	61	806	867	92.96
	Plat total		**377**	**7,211**	**7,588**	**95.03**
II	Arsenate of lead (paste), ½ pound to 50 gallons lime-sulphur solution	1	387	6,979	7,366	94.75
		2	221	5,282	5,503	95.98
		3	222	5,064	5,286	95.80
		4	355	5,098	5,453	93.49
		5	128	3,771	3,899	96.72
	Plat total		**1,313**	**26,194**	**27,507**	**95.22**

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
III	Arsenate of lead (powder), ½ pound to 50 gallons lime-sulphur solution	1	97	7,250	7,347	98.68
		2	123	5,615	5,738	97.85
		3	68	6,315	6,383	98.93
	Plat total		**288**	**19,180**	**19,468**	**98.52**
IV	Arsenate of lead (powder), ½ pound combined with commercial precipitated sulphur, 7 pounds, to 50 gallons water	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total		**219**	**22,367**	**22,586**	**99.03**
V	Arsenate of lead (paste), 1 pound to 50 gallons lime-sulphur solution	1	74	6,160	6,234	98.81
		2	39	4,163	4,202	99.07
		3	65	4,836	4,901	98.67
		4	64	6,394	6,458	99.01
		5	76	5,787	5,863	98.69
	Plat total		**318**	**27,340**	**27,658**	**98.13**
VI	Arsenate of lead (powder), 1 pound to 50 gallons lime-sulphur solution	1	123	5,043	5,166	97.62
		2	41	6,718	6,759	99.39
		3	79	5,418	5,497	98.56
		4	51	7,224	7,275	99.30
		5	121	7,749	7,870	98.46
	Plat total		**415**	**32,152**	**32,567**	**98.73**
VII	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total		**134**	**23,884**	**24,018**	**99.44**
VIII–X	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total		**19,764**	**28,102**	**47,866**	**58.71**

As will be noted in Table XVII, there is practically no difference from an insecticidal point of view in the effectiveness of the powdered and the paste arsenate of lead. The fruit grower would be justified in using the powdered form if the present difference in cost is considered reasonable for the advantages secured.

One-fourth pound of the powdered arsenate of lead gave 95.03 per cent of fruit free from codling moth against 95.22 per cent where one-half pound of the paste was used. The two plats sprayed with one-half pound of the powder gave 98.52 and 99.03 per cent of sound fruit, respectively, as compared with 98.13 per cent for 1 pound of the paste. One pound of the powder averaged 98.73 per cent sound

against 99.44 per cent for 2 pounds of the paste. The unsprayed trees yielded 47,866 apples, of which number 58.71 per cent were free from codling-moth infestation.

Experiment XVIII.

Field tests of various arsenicals combined with fungicides against the codling moth, 1914.

Arsenate of lead was tested against the codling moth in combination with the following commercial fungicides, namely, lime-sulphur, commercial; precipitated sulphur, commercial; sodium sulphid, commercial; and commercial barium tetrasulphid compound. The following combinations were also tested:

Arsenite of zinc (paste) was used at the rate of 1½ pounds combined with Bordeaux mixture 4–4–50. This arsenical was added to the lime while being slaked for the Bordeaux mixture.

Arsenite of zinc (paste), 1½ pounds, was added to 2 pounds stone lime while the lime was slaking. This was mixed with 50 gallons lime-sulphur solution.

Arsenate of zinc (homemade), prepared from sodium arsenate crystals and zinc sulphate, was used at the rate of eight-tenths pound sodium arsenate to 50 gallons lime-sulphur solution. Three spray applications were made with the above combinations. The results of this experiment will be found in Table XVIII.

Table XVIII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. Miscellaneous. Benton Harbor, Mich., 1914.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total		**134**	**23,884**	**24,018**	**99.44**
II	Arsenate of lead (powder), ½ pound + commercial precipitated sulphur, 7 pounds, to 50.	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total		**219**	**22,367**	**22,586**	**99.03**
III	Arsenate of lead (paste), 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	72	7,898	7,970	99.08
		2	30	7,784	7,814	99.62
		3	34	8,739	8,773	99.61
	Plat total		**136**	**24,421**	**24,557**	**99.45**
IV	Arsenate of lead (paste), 2 pounds + stone lime, 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	35	8,295	8,330	99.58
		2	22	6,269	6,291	99.65
		3	39	9,639	9,678	99.60
	Plat total		**96**	**24,203**	**24,299**	**99.65**

TABLE XVIII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
V	Arsenate of lead (paste), 2 pounds + commercial barium tetrasulphid 5–50.	1	806	9,224	10,030	90.97
		2	450	7,864	8,314	94.59
		3	216	6,988	7,204	97.00
		4	258	7,107	7,365	97.85
		5	328	10,340	10,668	96.91
	Plat total		**2,058**	**41,523**	**43,581**	**95.28**
VI	Arsenite of zinc (paste), 1½ pounds + Bordeaux mixture 4–4–50.	1	42	3,982	4,024	98.96
		2	29	5,121	5,150	99.44
		3	27	3,231	3,258	99.17
	Plat total		**98**	**12,334**	**12,432**	**99.21**
VII	Arsenite of zinc (paste), 1½ pounds + stone lime, 2 pounds, to 50 gallons lime-sulphur solution.	1	347	4,092	4,439	92.18
		2	244	5,478	5,722	95.74
		3	274	5,885	6,159	90.68
	Plat total		**865**	**15,455**	**16,320**	**94.70**
VIII	Arsenate of zinc (homemade), sodium arsenate crystals, $\frac{5}{10}$ pound, to 50 gallons lime-sulphur solution	1	221	3,654	3,875	94.30
		2	167	3,544	3,711	95.50
		3	309	5,306	5,615	94.50
	Plat total		**697**	**12,504**	**13,201**	**94.72**
IX–XI	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total		**19,764**	**28,102**	**47,866**	**58.71**

Arsenate of lead gave satisfactory control of the codling moth when combined with lime-sulphur, commercial precipitated sulphur, and commercial barium tetrasulphid. In combination with commercial sodium sulphid, lead arsenate held the codling moth in check, but caused considerable foliage injury and defoliation due to the formation of soluble sodium arsenate. The addition of lime lessened the foliage injury somewhat.

Arsenate of zinc, when added to lime being slaked for Bordeaux mixture, was effective and caused no foliage injury. Arsenite of zinc added to slaking lime and then mixed with lime-sulphur solution, and likewise arsenate of zinc (homemade) combined with lime-sulphur solution, were slightly less effective than the other arsenical combinations.

EXPERIMENT XIX.

COMBINATION SPRAYS—COMPATIBLES AND INCOMPATIBLES.

Combination sprays for the control of apple chewing and sucking insects and fungous diseases were tested in the experimental orchard. Arsenate of lead with nicotine solutions and lime-sulphur solution is a compatible mixture and will give satisfactory results if the application is timely.

Arsenate of lead, kerosene emulsion, and lime-sulphur in combination is an incompatible mixture, usually causing severe injury to the foliage. The calcium of the lime-sulphur breaks down the soap of the kerosene emulsion, forming an insoluble calcium soap. The result is that free kerosene is released in sufficient quantity to cause foliage injury.

A combination of lime-sulphur and kerosene emulsion, 10 per cent, was tested on apple in the cluster-bud stage to determine the extent of damage likely to occur. The plat which later received one-fourth pound to 50 of powdered arsenate of lead was used for the test. Both the foliage and unopened blossoms were so seriously injured as to reduce materially the size of the crop.

By reference to Table XVII the effect upon the crop yield will be noted. All plats in this table having five count trees were sprayed with lime-sulphur alone during the cluster-bud stage except Plat I. Plat I, which was sprayed with the combination of lime-sulphur and kerosene emulsion, yielded 7,588 apples (39 bushels); Plat II, 27,507 apples (109.5 bushels); Plat V, 27,658 apples (118 bushels); Plat VI, 32,567 apples (128.5 bushels). The number of bushels represents the amount of fruit picked from the trees at harvest time. An estimate of the loss of crop per tree due to the application of lime-sulphur and kerosene emulsion is approximately 16 bushels, or, in other words, the normal crop yield was reduced to about 33 per cent of that from the lime-sulphur plats alone.

Lime-sulphur and soap in combination is likewise impracticable, since a calcium soap is thrown out, thus weakening the value of each material.

Diplumbic arsenate of lead, especially the powdered form which is chiefly diplumbic, is likely to cause foliage injury when combined with an alkalin solution, such as sodium sulphid. But when combined with lime-sulphur some calcium arsenate is formed. This is comparatively insoluble, and hence the possibility of burning is reduced.

Experiment XX.

Comparison of soda, potash, and sulphur sprays against the San Jose scale.

The pear orchard owned by Mr. John Hamilton, of Benton Harbor, Mich., was used for the San Jose scale insecticide investigations. This orchard consisted of 209 trees about 15 years of age. Four varieties, planted in separate rows, were represented as follows: Three rows of Bartlett, one row Clairgeau, three rows Beurré d'Anjou, and one row Seckle. This orchard had been more or less neglected for several years and was accordingly quite uniformly infested with the scale. The orchard was divided into nine plats so as to include all varieties in each plat, so far as possible. Trees were left un-

sprayed at each end of the orchard and also in central sections as a basis for comparison with the sprayed. The spray materials were applied while the trees were dormant, April 10, 11, and 13, using a small power outfit.

To determine the efficacy of the scale insecticides two methods were employed; first, the examination of the scale-infested twigs for dead and live scales by means of the binocular microscope. This method proved to be anything but satisfactory. The second and better method of determining results was the examination of the fruit for scale which crawled thereon. All of the dropped fruit from the count trees was picked up and examined weekly throughout the season. The picked fruit at harvest time was also examined. In Table XIX will be found the results according to variety. Table XX is a commercial summary of Table XIX.

As will be noted in Table XX (commercial summary), the percentage of fruit (all varieties) free from scale and that with a light infestation has been combined for a comparison with the percentage of fruit with an infestation medium and heavy. The scale upon the fruit classified as lightly infested was usually found more or less concealed in the calyx cavity and, therefore, did not mar the appearance of the fruit for market. Furthermore, a large percentage of the fruit lightly infested had but two or three scales per fruit.

The fruit with a medium and heavy scale infestation was unmarketable. Frequently the fruit in the heavy scale infestation class was blood red in appearance and would average 500 to 1,000 scales per fruit. This condition was chiefly found on the unsprayed trees, whose foliage was likewise heavily infested with the scale insects.

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.				Number of fruits.				Per cent of fruit. Free from scale.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1-7	8	3	5	3	1,841	453	242	389	75.667	53.201	51.241	68.637
II	(1) Commercial sodium sulphid, 12.5 pounds-50	5	2	2	1	1,717	306	94	10	59.059	41.505	20.215	90.000
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds-50	2	0	3	2	1,008	0	191	1,522	25.101	.....	30.892	39.490
IV	(2) Commercial sodium sulphid, 12.5 pounds-50	0	2	3	0	0	435	238	0	.....	38.622	32.774	.....
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds-50	4	1	2	0	1,865	139	140	0	78.709	34.539	41.430	.....
VI	Lime-sulphur, 1-7—nitrate of soda, 50 pounds-50	6	0	2	2	946	0	113	15	76.289	.....	50.445	80.000
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds-50	5	1	2	1	1,531	143	208	521	89.877	51.750	70.194	54.892
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds-50	4	1	3	0	1,116	179	263	0	89.247	78.771	51.716	.....
IX	Check—unsprayed	33	2	11	3	8,100	299	1,825	4,474	52.595	25.420	8.056	6.841

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914*—Continued.

Plat.	Name and dilution.	Per cent of fruit.											
		Light infestation, 1–10 scales.				Medium infestation, 11–20 scales.				Heavy infestation, 21– over scales.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1–7	23.954	33.554	38.016	26.737	0.271	13.245	8.677	3.598	0.108	0	2.066	1.028
II	(1) Commercial sodium sulphid, 12.5 pounds–50	36.167	50.000	67.021	10.000	3.377	6.535	6.382	0	1.397	1.960	6.382	0
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds–50	61.111	.....	49.738	42.312	11.011	.....	7.339	6.570	2.777	.....	12.041	11.628
IV	(2) Commercial sodium sulphid, 12.5 pounds–50	.....	46.666	39.916	.....	.....	12.873	14.705	.....	.....	1.839	12.605	.....
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds–50	20.005	36.690	48.571	.....	1.018	21.561	7.857	.....	.268	7.19	2.142	.....
VI	Lime-sulphur, 1–7+nitrate of soda, 50 pounds–50	22.305	.....	40.707	20.000	1.313	.....	5.309	0	.093	.....	3.539	0
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds–50	9.797	46.153	28.365	39.731	.261	1.398	.961	4.418	.065	.699	.480	.959
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds–50	10.663	21.229	43.722	.....	.090	0	2.661	.....	0	0	1.901	.....
IX	Check—unsprayed	25.654	48.829	18.356	33.281	6.358	14.046	9.205	18.506	15.393	11.705	64.383	41.372

TABLE XX.—*San Jose scale insecticide investigations (commercial table), Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.	Total number of fruits.	Per cent of fruit.	
				Free from scale to light infestation, marketable.	Medium to heavy infestation, unmarketable.
I	Lime-sulphur, 1–7	19	2,925	98.052	1.948
II	(1) Commercial sodium sulphid, 12.5 pounds–50	11	2,127	94.359	5.641
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds–50	7	2,721	83.352	16.648
IV	(2) Commercial sodium sulphid, 12.5 pounds–50	5	673	80.833	19.167
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds–50	7	2,144	97.942	2.058
VI	Lime-sulphur, 1–7+nitrate of soda, 50 pounds–50	11	1,074	98.511	1.489
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds–50	8	2,403	98.378	1.622
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds–50	8	1,558	99.167	.833
IX–XI	Checks—unsprayed	49	14,693	60.793	39.207

Although the spray materials were subjected to a severe test, all, with the exception of the materials employed in Plats III and IV, gave satisfactory results. Lime-sulphur was used alone and also in combination with nitrate of soda. The addition of sodium nitrate did not affect the insecticidal value of the lime-sulphur. These plats yielded 98.052 and 98.511 per cent of marketable fruit, respectively. The homemade sodium and potassium sulphur solutions, with the exception of the materials used in Plat III, gave 97.972 to 99.167 per cent of

marketable fruit. Plat III (KOH, 11 pounds, and sulphur, 12.5 pounds), 83.352 per cent, No. 2 commercial sodium sulphid 80.833 per cent, and the unsprayed plats averaged but 60.793 per cent of marketable fruit.

Experiment XXI.

Field tests of various arsenicals combined with Bordeaux mixture on the foliage of grape.

Several arsenicals in combination with Bordeaux mixture (4–4–50) were tested on grape foliage at the vineyard of William Birkit, of Glenlord, Mich. Two applications were made with a power sprayer, June 23 and July 2, 1914, 50 gallons to the plat.

Plat I (applications 1 and 2), commercial arsenate of lead (powder), $1\frac{1}{2}$ to 50; Plat II (applications 1 and 2), arsenate of calcium, homemade (sodium arsenate crystals, 18 ounces + calcium chlorid to 50); Plat III (applications 1 and 2), arsenate of zinc, homemade (sodium arsenate crystals, 18 ounces + zinc sulphate to 50); Plat IV (application 1), commercial arsenate of calcium (paste), 3 to 50, (application 2) homemade arsenate of calcium (sodium arsenate crystals, 18 ounces + stone lime, 3 pounds to 50); Plat V (application 1), commercial arsenite of zinc (paste), $1\frac{3}{4}$ to 50 (application 2), commercial arsenite of zinc (powder), 18 ounces to 50.

No foliage injury resulted from the applications of these arsenicals.

SUMMARIZED REVIEW.

ARSENATE OF LEAD.

LABORATORY TESTS.

Used alone.—Arsenate of lead was used throughout the experimental work as a basis of comparison for the other compounds tested. The rapidity of killing was greatest with diplumbic arsenate of lead, while the triplumbic form was the slowest. Arsenate of lead of a mixed diplumbic and triplumbic composition closely approached the effectiveness of the diplumbic form. Commercial arsenate of lead No. 1 (triplumbic) was likewise slower in killing than the other commercial compounds, which were largely diplumbic. In tests with the several forms of arsenate of lead upon tender foliage, the triplumbic, the most insoluble form, was found to be the safest.

With kerosene emulsion.—Arsenate of lead may be combined with kerosene emulsion for the purpose of combating mandibulate and haustellate insects. Although there is a slight breaking down of the materials, the value of neither material is depreciated when used jointly as a spray. In order to secure the best results, it is advisable not to mix these materials until needed. In a general way this is applicable to the use of most insecticides in combination.

With lime-sulphur.—Triplumbic arsenate of lead combined with lime-sulphur solution again proved to have a slower toxic effect than either di or di and tri arsenates so combined. The triplumbic commercial No. 1 arsenate of lead was again less rapid as a poisoning agent than the commercial products of diplumbic compositions. It was found that the mixing of lime-sulphur and arsenate of lead results in a smaller consumption of foliage than when arsenate of lead is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—Arsenate of lead consistently proved to be the most effective poison tested during the three years of experimentation. Triplumbic arsenate with lime-sulphur did not hold the codling moth in check quite as well as the ordinary commercial (diplumbic) arsenate of lead. Powdered arsenate of lead is equally as effective as the paste form for the control of the codling moth.

LABORATORY AND FIELD TESTS.

With commercial sodium sulphid No. 1.—The value of arsenate of lead is not decreased when combined with sodium sulphid; in fact the sodium arsenate formed is more active as a toxin than lead arsenate. However, field experiments with apples show that this combination is impracticable, owing to the frequency of foliage injury due to the formation of the soluble sodium arsenate.

With commercial barium tetrasulphid.—Arsenate of lead mixed with barium tetrasulphid was used with satisfactory results for the control of the codling moth. This combination was found safe for use on apple foliage.

With nicotine solutions and lime-sulphur.—Arsenate of lead may be mixed with nicotine solutions and lime-sulphur for the control of certain apple sucking and chewing insects, as well as fungous diseases. The mixing of these materials does not lessen their individual value and moreover may be applied to apple foliage with safety.

With kerosene emulsion and lime-sulphur.—The combination of lead arsenate, kerosene emulsion, and lime-sulphur should not be used as an orchard spray, owing to the breaking down of the materials and the subsequent foliage injury.

With fish-oil soap and lime-sulphur.—The combination of arsenate of lead, fish-oil soap, and lime-sulphur is not a compatible mixture for spraying purposes, since an insoluble calcium soap is formed. In our experience, any combination containing lime-sulphur and soap should not be used.

ARSENATE OF CALCIUM.

An effort was made to secure a satisfactory substitute for arsenate of lead, a compound which would be as efficient and at the same time less costly. With this object in view arsenate of calcium was used

in the experimental work during 1912, 1913, and 1914, and has given encouraging results. This arsenical can undoubtedly be manufactured at a somewhat cheaper cost than arsenate of lead. It is of further interest to note that this compound may be readily prepared at home by combining fused sodium arsenate with stone lime. (For a discussion of the method of making, see p. 30.) While it would be preferable to use arsenic acid in place of sodium arsenate, this acid can not be readily secured at low cost at the present time. When arsenic acid is used the method of preparation as described should be modified somewhat.

LABORATORY TESTS.

Used alone.—Arsenate of calcium, commercial powder and paste and homemade paste, in accordance with several formulas, was used in poison-feeding tests with several species of chewing insects. In some instances the rapidity of killing was equal to that of arsenate of lead, but was generally somewhat less.

With lime-sulphur.—With lime-sulphur, arsenate of calcium was as a rule more effective as a poisoning agent than when used alone. When these compounds are combined, the amount of foliage consumed by the larvæ is less than when arsenate of calcium is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—During the years 1912 and 1913 the several forms of arsenate of calcium combined with lime-sulphur gave fairly satisfactory control of the codling moth, considering the strength of the arsenical used. In 1914 a commercial arsenate of calcium (paste), arsenic oxid 18.82 per cent, combined with lime-sulphur solution, gave very excellent control of the codling moth in comparison with arsenate of lead and unsprayed plats; arsenate of calcium, 29,269 apples, 98.79 per cent sound; arsenate of lead, 24,018 apples, 99.44 per cent sound; unsprayed, 47,866 apples, 58.71 per cent sound. It is of further interest to note that arsenate of calcium may be combined with lime-sulphur without lessening the value of the latter as a fungicide.

FIELD TESTS WITH GRAPE.

With Bordeaux mixture.—Commercial arsenate of calcium and homemade compounds were used combined with Bordeaux mixture in vineyard experiments. These combinations caused no foliage injury.

ARSENATE OF IRON.

LABORATORY AND FIELD TESTS.

Arsenate of iron is a slower acting poison than many of the other arsenicals tested. Laboratory tests, even at increased strengths, show that this arsenical is not quick to kill. In the field tests at the

experimental apple orchard arsenate of iron was not an effective insecticide for the codling moth. When used at greater strengths, however, this arsenical should give fairly satisfactory results, but would have no advantages over arsenate of lead.

ARSENATE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenate of zinc was used with very fair success in laboratory and field tests, but fell somewhat below the efficiency of arsenate of lead. This arsenical has no distinct advantages over arsenate of lead.

ARSENITE OF LIME.

LABORATORY AND FIELD TESTS.

Arsenite of lime is an active and relatively cheap arsenical poison. Unfortunately, however, its use is frequently attended with injury to the foliage.

ARSENITE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenite of zinc was used in both the paste and powdered forms alone and combined with fungicides. In common with other arsenites the zinc compound is an active poison, but frequently causes foliage injury. Arsenite of zinc combined with milk of lime and arsenite of zinc mixed with lime-sulphur caused considerable burning in the experimental apple orchard during 1912. In 1914 arsenite of zinc (paste) added to slaking lime and then mixed with lime-sulphur solution gave practically no foliage injury, but the value of the arsenical was apparently impaired. Arsenite of zinc (paste) added to slaking lime for Bordeaux mixture gave excellent codling-moth control and caused no foliage injury. It is possible that the latter combination may be of value in sections where apple growers use Bordeaux mixture along with an arsenical for the control of the codling moth, bitter-rot, and blotch. Commercial arsenite of zinc in combination with Bordeaux mixture was tested in a vineyard during the season of 1914, with satisfactory results.

MISCELLANEOUS ARSENICALS.

The following arsenical compounds were also tested at the laboratory: Arsenic sulphid, arsenic tersulphid, and arsenic trioxid. These materials are destructive to leaf tissue and therefore undesirable insecticides.

Nonarsenical Compounds.

Several compounds containing no arsenic were tested, namely, barium chlorid, barium sulphate, calcium chlorid, copper oxid, lead acetate, lead carbonate, lead chromate, lead oxid, lead peroxid,

mercury bichlorid, zinc chlorid, zinc oxid, and zinc sulphate. While some of these compounds gave more or less satisfactory results, they were not of sufficient promise to warrant further testing.

SODIUM AND POTASSIUM SULPHUR SOLUTIONS.

Caustic soda and caustic potash (homemade and commercial) were combined with sulphur for the control of the San Jose scale. Certain of the solutions proved to be generally satisfactory as scalecides, in some instances equaling lime-sulphur solution. Such solutions can be readily prepared at home without the use of heat.

CONCLUSIONS.

During the course of the experimental work information on the value of many compounds and combination sprays has been secured. Several of the materials proved to be less valuable than those now in common use, owing to their slow killing effect, to their injury to foliage, to their cost, or to their incompatibility. While many of the compounds proved to be impracticable for insecticidal purposes, certain new spray materials and combinations were used with success. Since the prevention of fungous diseases is intimately associated with insect control, many of the insecticides were tested with a fungicide in order to ascertain the results of such a combination.

Arsenate of lead proved to be the most consistent and valuable stomach poison tested, giving satisfactory results throughout the experimental work.

Arsenate of lead is equally effective in either the paste or powdered form.

Triplumbic arsenate of lead is less rapid as a poisoning agent than diplumbic arsenate, but is safer for use on tender foliage.

Arsenate of lead may be combined with nicotine solutions and lime-sulphur solution for the control of certain apple chewing and sucking insects, and fungous diseases.

For the control of certain sucking and chewing insects arsenate of lead may be combined with kerosene emulsion.

Arsenate of lead, kerosene emulsion, and lime-sulphur is an incompatible mixture, due to the formation of an insoluble calcium soap and the subsequent release of free kerosene. In our experience any combination containing lime-sulphur and soap should not be used, owing to the formation of an insoluble calcium soap.

Arsenate of lead should not be mixed with sodium sulphid compounds, since the soluble sodium arsenate formed is destructive to leaf tissue.

Arsenate of lead combined with a commercial barium tetrasulphid gave satisfactory control of the codling moth and caused no foliage injury in the experimental apple orchard.

The most promising new insecticide developed during the course of the experimental work is arsenate of calcium. This arsenical may be manufactured at less cost than arsenate of lead or may be readily prepared at home as described on page 30. During the seasons of 1912 and 1913 arsenate of calcium gave encouraging results. In 1914 a commercial arsenate of calcium paste in combination with lime-sulphur gave very satisfactory control of the codling moth. While arsenate of calcium may have certain limitations, it will doubtless prove of value for the control of chewing insects on certain host plants.

Arsenate of iron and arsenate of zinc are not as satisfactory as arsenate of lead.

Arsenite compounds are dangerous to use on tender foliage. In some instances, however, it may be possible to prevent foliage injury somewhat by combining the soluble arsenic with lime.

Sodium-sulphur and potassium-sulphur compounds gave fairly satisfactory control of the San Jose scale, in some instances equaling lime-sulphur solution. They may readily be prepared at home without the use of heat.

KEY TO THE TABLES OF INSECTICIDES AND COMBINATION SPRAYS USED IN THIS BULLETIN.

[Com=commercial; c. p.=chemically pure; h. m.=homemade.]

Reference.	Table.
Anthracene emulsion	XI, XV
Anthracene emulsion, arsenate of lead (powder)	XI
Arsenate of calcium (com. paste)	VI, XIII, XIV
Arsenate of calcium (com. paste), kerosene emulsion	XIII
Arsenate of calcium (com. paste), lime-sulphur	VI, X, XIII, XIV, XVI
Arsenate of calcium (com. powder)	VIII, XI, XIII, XIV
Arsenate of calcium (com. powder), kerosene emulsion	XI
Arsenate of calcium (com. powder), lime-sulphur	XIV
Arsenate of calcium (c. p. powder)	I, III, V
Arsenate of calcium (c. p. powder), lime	V
Arsenate of calcium (c. p. powder), lime-sulphur	II, IV, V
Arsenate of calcium (h. m. paste)	VI, VIII, IX, XIII, XIV
Arsenate of calcium (h. m. paste), Bordeaux mixture	XII
Arsenate of calcium (h. m. paste), Bordeaux mixture, nicotine sulphate	XII
Arsenate of calcium (h. m. paste), kerosene emulsion	XIII
Arsenate of calcium (h. m. paste), lime-sulphur	VI, X, XIII, XIV
Arsenate of calcium (h. m.), self-boiled lime-sulphur	XIII
Arsenate of iron (c. p. powder)	I, III, V
Arsenate of iron (c. p. powder), lime	V
Arsenate of iron (c. p. powder), lime-sulphur	II, IV, V
Arsenate of iron (h. m. paste)	I, III, V
Arsenate of iron (h. m. paste), lime	V
Arsenate of iron (h. m. paste), lime-sulphur	II, IV, V
Arsenate of lead (com. paste)	I, III, V, VI, VII, VIII, IX, XIII, XIV, XV
Arsenate of lead (com. paste), barium tetrasulphid	XVIII
Arsenate of lead (com. paste), kerosene emulsion	XIII

Table.
Arsenate of lead (com. paste), laundry soap, nicotine sulphate..... XV
Arsenate of lead (com. paste), lime..... V
Arsenate of lead (com. paste), lime-sulphur..... II, IV, V, VI, X, XIII, XIV, XVI, XVII, XVIII
Arsenate of lead (com. paste), nicotine sulphate..... XV
Arsenate of lead (com. paste), nicotine sulphate, lime-sulphur..... XV
Arsenate of lead (com. paste), self-boiled lime-sulphur..... XIII
Arsenate of lead (com. paste), sodium sulphid (com.)..... XVIII
Arsenate of lead (com. paste), sodium sulphid (com.), lime..... XVIII
Arsenate of lead (com. powder)..... VIII, XI, XII
Arsenate of lead (com. powder), anthracene emulsion..... XI
Arsenate of lead (com. powder), barium tetrasulphid..... XII
Arsenate of lead (com. powder), kerosene emulsion..... XI
Arsenate of lead (com. powder), lime-sulphur..... XII, XVII
Arsenate of lead (com. powder), sodium sulphid (com.)..... XII
Arsenate of lead (com. powder), sulphur (com. precipitated)..... XVIII
Arsenate of lead (diplumbic powder)..... I, III, V
Arsenate of lead (diplumbic powder), lime..... V
Arsenate of lead (diplumbic powder), lime-sulphur..... II, V
Arsenate of lead (di and triplumbic powder)..... I, III, V
Arsenate of lead (di and triplumbic powder), lime..... V
Arsenate of lead (di and triplumbic powder), lime-sulphur..... II, V
Arsenate of lead (triplumbic powder)..... I, III, V
Arsenate of lead (triplumbic powder), lime..... V
Arsenate of lead (triplumbic powder), lime-sulphur..... II, IV, V
Arsenate of lead (triplumbic com. paste)..... I, III, V
Arsenate of lead (triplumbic com. paste), lime..... V
Arsenate of lead (triplumbic com. paste), lime-sulphur..... II, IV, V
Arsenate of zinc (c. p. powder)..... I, III, V
Arsenate of zinc (c. p. powder), lime..... V
Arsenate of zinc (c. p. powder), lime-sulphur..... II, V
Arsenate of zinc (h. m. paste)..... I, III, V, VIII, IX
Arsenate of zinc (h. m. paste), lime..... V
Arsenate of zinc (h. m. paste), lime-sulphur..... II, IV, V, X, XVIII
Arsenic sulphid..... I, III, V
Arsenic sulphid, lime-sulphur..... II
Arsenic tersulphid..... I, III, V
Arsenic tersulphid, lime-sulphur..... II
Arsenic trioxid..... I, III, V
Arsenic trioxid, lime-sulphur..... II
Arsenite of lime (h. m. paste)..... I, III, V
Arsenite of lime (h. m. paste), lime..... V
Arsenite of lime (h. m. paste), lime-sulphur..... II, IV, V
Arsenite of zinc (com. paste)..... I, III, V
Arsenite of zinc (com. paste), Bordeaux mixture..... XVIII
Arsenite of zinc (com. paste), lime..... V
Arsenite of zinc (com. paste), lime, lime-sulphur..... XVIII
Arsenite of zinc (com. paste), lime-sulphur..... II, IV, V
Arsenite of zinc (com. powder)..... I, III, V, VIII, IX, XI
Arsenite of zinc (com. powder), kerosene emulsion..... XI
Arsenite of zinc (com. powder), lime..... V
Arsenite of zinc (com. powder), lime-sulphur..... II, IV, V, X
Arsenite of zinc (c. p. powder)..... I, III, V

	Table.
Arsenite of zinc (c. p. powder), lime	V
Arsenite of zinc (c. p. powder), lime-sulphur	II, V
Barium chlorid	I
Barium chlorid, lime-sulphur	II
Barium sulphate	I
Barium sulphate, lime-sulphur	II
Barium tetrasulphid (com.)	XII
Barium tetrasulphid (com.), arsenate of lead (com. paste)	XVIII
Barium tetrasulphid (com.), arsenate of lead (com. powder)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste), nicotine sulphate	XII
Bordeaux mixture, arsenite of zinc (com. paste)	XVIII
Calcium chlorid	I
Calcium chlorid, lime-sulphur	II
Copper oxid	I
Copper oxid, lime-sulphur	II
Kerosene emulsion	XI, XIII, XV
Kerosene emulsion, arsenate of calcium (com. paste)	XIII, XV
Kerosene emulsion, arsenate of calcium (com. powder)	XI
Kerosene emulsion, arsenate of calcium (h. m. paste)	XIII
Kerosene emulsion, arsenate of lead (com. paste)	XIII, XV
Kerosene emulsion, arsenate of lead (com. powder)	XI
Kerosene emulsion, arsenite of zinc (com. powder)	XI
Lead acetate	I
Lead acetate, lime-sulphur	II
Lead carbonate	I
Lead carbonate, lime-sulphur	II
Lead chromate (com. powder)	I, VII, VIII, IX
Lead chromate (com. powder), lime-sulphur	II
Lead chromate (h. m. paste)	VII, VIII
Lead oxid	I
Lead oxid, lime-sulphur	II
Lead peroxid	I
Lead peroxid, lime-sulphur	II
Lime, arsenate of calcium (c. p. powder)	V
Lime, arsenate of iron (c. p. powder)	V
Lime, arsenate of iron (h. m. paste)	V
Lime, arsenate of lead (com. paste)	V
Lime, arsenate of lead (com. paste), sodium sulphid (com.)	XVIII
Lime, arsenate of lead (diplumbic powder)	V
Lime, arsenate of lead (di and triplumbic powder)	V
Lime, arsenate of lead (triplumbic powder)	V
Lime, arsenate of lead (triplumbic paste)	V
Lime, arsenate of zinc (c. p. powder)	V
Lime, arsenate of zinc (h. m. paste)	V
Lime, arsenite of lime (h. m. paste)	V
Lime, arsenite of zinc (com. paste)	V
Lime, arsenite of zinc (com. paste), lime-sulphur	XVIII
Lime, arsenite of zinc (com. powder)	V
Lime, arsenite of zinc (c. p. powder)	V
Lime, paris green	V
Lime-sulphur	II, V, XII, XIV, XIX, XX
Lime-sulphur, arsenate of calcium (com. paste)	VI, X, XIII, XIV, XVI

Table.
Lime-sulphur, arsenate of calcium (com. powder) XIV
Lime-sulphur, arsenate of calcium (c. p. powder) ..... II, IV, V
Lime-sulphur, arsenate of calcium (h. m. paste) ..... VI, X, XIII, XIV
Lime-sulphur, arsenate of iron (c. p. powder) ..... II, IV, V
Lime-sulphur, arsenate of iron (h. m. paste) ..... II, IV, V
Lime-sulphur, arsenate of lead (com. paste) ..... II, IV, V, VI, X, XIII, XIV, XVI, XVII, XVIII
Lime-sulphur, arsenate of lead (com. paste), nicotine sulphate XV
Lime-sulphur, arsenate of lead (com. powder) ..... XII, XVII
Lime-sulphur, arsenate of lead (diplumbic powder) ..... II, V
Lime-sulphur, arsenate of lead (di and triplumbic powder) ..... II, V
Lime-sulphur, arsenate of lead (triplumbic powder) ..... II, IV, V
Lime-sulphur, arsenate of lead (triplumbic com. paste) ..... II, IV, V
Lime-sulphur, arsenate of zinc (c. p. powder) ..... II, V
Lime-sulphur, arsenate of zinc (h. m. paste) ..... II, IV, V, X, XVIII
Lime-sulphur, arsenic sulphid II
Lime-sulphur, arsenic tersulphid II
Lime-sulphur, arsenic trioxid II
Lime-sulphur, arsenite of lime (h. m. paste) ..... II, IV, V
Lime-sulphur, arsenite of zinc (com. paste) ..... II, IV, V
Lime-sulphur, arsenite of zinc (com. paste), lime XIX
Lime-sulphur, arsenite of zinc (com. powder) ..... II, IV, V, X
Lime-sulphur, arsenite of zinc (c. p. powder) ..... II, V
Lime-sulphur, barium chlorid II
Lime-sulphur, barium sulphate II
Lime-sulphur, calcium chlorid II
Lime-sulphur, copper oxid II
Lime-sulphur, lead acetate II
Lime-sulphur, lead carbonate II
Lime-sulphur, lead chromate (com. powder) II
Lime-sulphur, lead oxid II
Lime-sulphur, peroxid II
Lime-sulphur, mercury bichlorid II
Lime-sulphur, nitrate of soda ..... XIX, XX
Lime-sulphur, Paris green V
Lime-sulphur, zinc chlorid II
Lime-sulphur, zinc oxid II
Lime-sulphur, zinc sulphate II
Mercury bichlorid I
Mercury bichlorid, lime-sulphur II
Nicotine sulphate XV
Nicotine sulphate, arsenate of lead (com. paste) XV
Nicotine sulphate, arsenate of lead (com. paste), laundry soap XV
Nicotine sulphate, arsenate of lead (com. paste), lime-sulphur XV
Nicotine sulphate, laundry soap XV
Nitrate of soda, lime-sulphur ..... XIX, XX
Paris green V
Paris green, lime V
Paris green, lime-sulphur V
Potassium sulphid (h. m.) ..... XIX, XX
Self-boiled lime-sulphur, arsenate of calcium (h. m. paste) XIII
Self-boiled lime-sulphur, arsenate of lead (com. paste) XIII
Soap (fish oil) XV

	Table.
Soap (laundry)	XV
Soap (laundry), arsenate of lead (com. paste)	XV
Soap (laundry), arsenate of lead (com. paste), nicotine sulphate	XV
Soap (laundry), nicotine sulphate	XV
Soap (naphtha)	XV
Sodium sulphid (com.)	XII, XIX, XX
Sodium sulphid (com.), arsenate of lead (com. paste)	XVIII
Sodium sulphid (com.), arsenate of lead (com. paste), lime	XVIII
Sodium sulphid (com.), arsenate of lead (com. powder)	XII
Sodium sulphid (h. m.)	XIX, XX
Sulphur (com. precipitated), arsenate of lead (com. powder)	XVIII
Zinc chlorid	I
Zinc chlorid, lime-sulphur	II
Zinc oxid	I
Zinc oxid, lime-sulphur	II
Zinc sulphate	I
Zinc sulphate, lime-sulphur	II

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

▽